Blacks Fork Watershed
Total Maximum Daily Loads

Public Draft Report

Prepared for

Wyoming Department of Environmental Quality

Prepared by

SWCA Environmental Consultants

June 2014

BLACKS FORK WATERSHED
TOTAL MAXIMUM DAILY LOADS

PUBLIC DRAFT REPORT

Prepared for

Wyoming Department of Environmental Quality
122 West 25th Street
Herschler Building, 4-West
Cheyenne, Wyoming 82002
Attn: Kevin Hyatt
(307) 777-8582

Prepared by

SWCA Environmental Consultants
257 East 200 South, Suite 200
Salt Lake City, Utah 84111
(801) 322-4307
www.swca.com

June 2014

VERSION LOG

Document Status	Date Submitted	Submitted To	Submitted By
Administrative Draft	05/02/2014	WDEQ	SWCA
Public Draft	06/09/2014	WDEQ	SWCA

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
WATER QUALITY DIVISION
BLACKS FORK WATERSHED PATHOGEN TMDLs

TMDL SUMMARY TABLE

Waterbody Name	**Blacks Fork River**
Waterbody ID	WYGR140401070106_01
Location	Blacks Fork from Smiths Fork upstream to Millburne
Causes of Impairment	Fecal coliform (converted to *Escherichia coli* [E. coli])
Impaired Designated Uses	2AB, Recreation
List Date	2000
Current Load (giga colony forming unit [G-cfu]/season)	Impairment season: 59,863 G-cfu/season (394 G-cfu/day) Critical 60-day period season: 22,264 G-cfu/season (371 G-cfu/day)
TMDL (G-cfu/season)	Impairment season: 20,952 G-cfu/season (138 G-cfu/day) Critical 60-day period season: 7,792 G-cfu/season (130 G-cfu/day)
Margin of Safety (G-cfu/season)	0
Wastewater Treatment Plant Wasteload Allocations (G-cfu/impairment season)	Fort Bridger Sewer (WY0022071): 257 Travel Centers of America (WY0036153): 10 Town of Lyman (WY0020117): 326 **Total: 593**
Nonpoint Source Load Allocations (G-cfu/impairment season)	Upstream: 534 Diverted: 1,819 Septic systems: 723 Pet waste: 270 Wildlife: 1,460 Livestock: 15,239 **Total: 20,046**
Future Growth Wasteload Allocations (G-cfu/impairment season)	215
Defined Targets/Endpoints (*E. coli*)	Standard during the summer recreation season (May 1–September 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters during any consecutive 60-day period. Standard during the winter recreation season (October 1–April 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 630 organisms per 100 milliliters during any consecutive 60-day period.

Waterbody Name	**Blacks Fork River**
Waterbody ID	WYGR140401070403_01
Location	Blacks Fork from Hams Fork upstream to Smiths Fork
Causes of Impairment	*E. coli*
Impaired Designated Uses	2AB, Recreation
List Date	2000
Current Load (G-cfu/ season)	Impairment season: 2,903 G-cfu/season (19 G-cfu/day) Critical 60-day period season: 436 G-cfu/season (7 G-cfu/day)
TMDL (G-cfu/ season)	Impairment season: 2,903 G-cfu/season (19 G-cfu/day) Critical 60-day period season: 436 G-cfu/season (7 G-cfu/day)
Margin of Safety (G-cfu/ season)	0
Wasteload Allocations (G-cfu/impairment season)	None
Nonpoint Source Load Allocations (G-cfu/impairment season)	Upstream: 1,306 Diverted: 0 Septic systems: 1 Pet waste: 0 Wildlife: 448 Livestock: 1,148 **Total: 2,903**
Future Growth Wasteload Allocations (G-cfu/impairment season)	0
Defined Targets/Endpoints (*E. coli*)	Standard during the summer recreation season (May 1–September 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters during any consecutive 60-day period. Standard during the winter recreation season (October 1–April 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 630 organisms per 100 milliliters during any consecutive 60-day period.

Waterbody Name	**Smiths Fork River**
Waterbody ID	WYGR140401070208_01
Location	Smiths Fork from Blacks Fork upstream to Cottonwood Creek
Causes of Impairment	*E. coli*
Impaired Designated Uses	2AB, Recreation
List Date	2000
Current Load (G-cfu/season)	Impairment season: 92,697 G-cfu/season (612 G-cfu/day) Critical 60-day period season: 43,750 G-cfu/season (729 G-cfu/day)
TMDL (G-cfu/season)	Impairment season: 26,882 G-cfu/season (177 G-cfu/day) Critical 60-day period season: 12,688 G-cfu/season (212 G-cfu/day)
Margin of Safety (G-cfu/season)	0
Wasteload Allocations (G-cfu/impairment season)	None
Nonpoint Source Load Allocations (G-cfu/impairment season)	Upstream: 22,215 Diverted: 0 Septic systems: 0 Pet waste: 1 Wildlife: 851 Livestock: 3,815 **Total: 26,882**
Future Growth Wasteload Allocations (G-cfu/impairment season)	0
Defined Targets/Endpoints (*E. coli*)	Standard during the summer recreation season (May 1–September 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters during any consecutive 60-day period. Standard during the winter recreation season (October 1–April 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 630 organisms per 100 milliliters during any consecutive 60-day period.

Waterbody Name	**Smiths Fork River**
Waterbody ID	WYGR140401070208_00
Location	Smiths Fork from Cottonwood Creek upstream to East Fork and West Fork of Smiths Fork
Causes of Impairment	Fecal coliform (converted to *E. coli*)
Impaired Designated Uses	2AB, Recreation
List Date	2000
Current Load (G-cfu/season)	Impairment season: 196,078 G-cfu/season (1,290 G-cfu/day) Critical 60-day period season: 102,432 G-cfu/season (1,707 G-cfu/day)
TMDL (G-cfu/season)	Impairment season: 27,451 G-cfu/season (181 G-cfu/day) Critical 60-day period season: 14,430 G-cfu/season (241 G-cfu/day)
Margin of Safety (G-cfu/season)	0
Wastewater Treatment Plant Wasteload Allocations (G-cfu/impairment season)	Town of Mountain View (WY0022896): 292 **Total: 292**
Nonpoint Source Load Allocations (G-cfu/impairment season)	Upstream: 0 Diverted: 2,621 Septic systems: 556 Pet waste: 113 Wildlife: 1,410 Livestock: 22,053 **Total: 26,753**
Future Growth Wasteload Allocations (G-cfu/impairment season)	407
Defined Targets/Endpoints (*E. coli*)	Standard during the summer recreation season (May 1–September 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters during any consecutive 60-day period. Standard during the winter recreation season (October 1–April 30): concentrations of *E. coli* bacteria shall not exceed a geometric mean of 630 organisms per 100 milliliters during any consecutive 60-day period.

EXECUTIVE SUMMARY

This document represents the total maximum daily load (TMDL) analyses of four impaired reaches of the Blacks Fork and Smiths Fork Rivers within the greater Blacks Fork Watershed in fulfillment of Clean Water Act requirements (Figure 1.1). A TMDL analysis determines the amount of an identified pollutant (i.e., the load) that a waterbody can receive while preserving its designated uses and state water quality standards. Once the pollutant loads have been identified, controls are implemented to reduce those loads until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL analysis, it is submitted to the Wyoming Department of Environmental Quality (WDEQ) and the U.S. Environmental Protection Agency (EPA) for approval.

The overall goal of the TMDL process within the greater Blacks Fork Watershed is to restore and maintain water quality in the impaired reaches of the Blacks Fork and Smiths Fork Rivers to a level that protects and supports their designated uses (e.g., drinking water, game and non-game fish, fish consumption, other aquatic life, recreation, wildlife, agriculture, industry, and scenic value). SWCA Environmental Consultants developed this TMDL under the direction of the Wyoming Department of Environmental Quality (WDEQ).

WDEQ's Water Quality Division (WQD) collects biological and water quality data to evaluate the quality of the waters of the State of Wyoming. Based on this assessment, two reaches of Blacks Fork and two reaches of Smiths Fork were included on the State of Wyoming's 303(d) list in 2000 for exceedances in *Escherichia coli* (*E. coli*) and fecal coliform. It should be noted that recent data from Reach 2 (see Figure 1.1) indicate that an impairment no longer exists; however, it has not been officially delisted and therefore still maintains a "not supporting" designation. As such, it is considered in the source analysis assuming a 0% reduction. This report defines the TMDLs and water quality targets that, when attained, will bring the three impaired reaches of the Blacks Fork and Smiths Fork Rivers into full support of the uses designated by the State of Wyoming. The Blacks Fork Watershed is in the Bridger Valley region of Uinta County in southwestern Wyoming. The region was settled in the mid-1800s and was an epicenter for fur trading. It currently serves as a major recreational access point to the Uinta Mountains. In 2010, Uinta County had an estimated population of 21,118 and has increased at an average of 5.5% annually in recent years (U.S. Census Bureau 2010). Major towns in the region include Lyman, Fort Bridger, and Mountain View, which have increased in growth by approximately 8% from 2000 to 2010.

The Blacks Fork Watershed is in a semiarid and mountainous region of southwestern Wyoming. Elevation in the watershed ranges from 13,212 feet in the headwaters regions to 6,260 feet in the Lower Blacks Fork near the town of Granger, Wyoming. The Blacks Fork Watershed drains approximately 1,343,732 acres of forest, agricultural, rural, and semi-urban environments. Surface waters in the Blacks Fork Watershed are primarily used to provide irrigation water to many rural dwelling and town residents.

The Blacks Fork Watershed has two primary drainages: Blacks Fork and Smiths Fork. The headwaters of the Blacks Fork are high in the Uinta Mountains at an elevation of approximately 13,000 feet. The Blacks Fork flows north through Uinta County, Wyoming, before joining with Smiths Fork, and then turning south where it eventually terminates in Flaming Gorge Reservoir. Smiths Fork also originates in the Uinta Mountains at an elevation of approximately 13,000 feet and flows northeast for approximately 68 miles before joining the Blacks Fork River northeast of the town of Lyman. Land uses vary greatly in the Blacks Fork Watershed and include semi-urban areas, agriculture lands, irrigated and non-irrigated hay meadows, wildlife habitat, and rangeland.

Hydrologic data from 1977 to 2007 were primarily provided by the Blacks Fork Basin model developed by the Wyoming State Engineer's Office. Spatial data were provided at a network of hydrologic nodes throughout the watershed, and years were categorized by normal, dry, and wet climate conditions. U.S.

Geological Survey flow data from 2008 to 2013 were also provided. Hydrographs show a typical snowmelt-dominated hydrology expected in southwestern Wyoming, with peak flows generally occurring around June during a normal year. Spring runoff may begin as early as mid-March, whereas low flows occur in August and endure throughout the winter. In the Blacks Fork Watershed, reservoirs are prevalent and store spring snowmelt for irrigation use in the valley lowlands. Below the reservoirs, water is diverted through numerous irrigation diversion canals and ditches at approximately 44 diversion locations that take over 130,000 acre-feet per year from the system (Wyoming Water Development Commission 2000, 2009).

Water quality data gathered from 2002 to 2013 were used for analysis in this TMDL. Data were obtained from the Uinta County Conservation District (UCCD), the Utah Department of Environmental Quality (UDEQ), and the WDEQ. The WDEQ and UCCD provided water quality data collected from multiple sites within the watershed below Stateline Dam on Smiths Fork and below Meeks Cabin Dam on Blacks Fork. The UCCD has been actively monitoring water quality, including *E. coli*, at several sites on the Blacks Fork and Smiths Fork since 2002 as part of the *Blacks Fork/Smiths Fork Watershed Report* (WWC Engineering 2006). STORET was queried to obtain UDEQ data from the upper watershed. These data were compiled into a single database used for multiple analyses to support development of the TMDL.

The TMDL identifies the current levels of *E. coli* loads, the established limits for *E. coli* (TMDL) based on the WDEQ standard, and the amount needed to be reduced for the impaired reaches of the Blacks Fork Watershed. *E. coli* loads associated with different hydrologic regimes are presented and described separately for each of three seasons (spring, summer, and fall) during three climate conditions (normal, dry, and wet) for all subwatersheds associated with the impaired reach. Analysis of available data indicates that the most likely source of *E. coli* to the impaired reaches is livestock. Nonpoint source loads from wildlife, irrigation, and septics comprise the remaining *E. coli* load. There are four point sources of *E. coli* in the Blacks Fork Watershed: one discharges directly to an impaired reach, two discharge to tributaries of impaired reaches, and one discharges to a contained wetland. Point sources make up less than 1% of the total *E. coli* load to impaired reaches during the entire impairment season (May–September). The overall *E. coli* load reduction required for the four impaired reaches ranges from 0 giga colony forming unit (G-cfu)/season to 124,540 G-cfu/season, which translates to a 0%–86% reduction.

A watershed-based implementation plan was developed for the Blacks Fork Watershed. This plan outlines a strategy to reduce *E. coli* loads and to attain Wyoming's water quality standards for the impaired reaches of the Blacks Fork and Smiths Fork Rivers. This implementation plan was developed for and will be submitted to stakeholders in the watershed. It includes the nine key elements identified by the U.S. Environmental Protection Agency.

Recommended management and implementation measures to reduce *E. coli* loads are defined and described in the implementation plan as potential tools for watershed stakeholders. These management measures focus on a variety of nonpoint sources that include contributions from livestock, irrigation, wildlife, and septic systems. In addition, financial and technical resources are identified for each management measure so that stakeholders can estimate time and labor costs for recommended strategies. Furthermore, an implementation schedule and milestones for nonpoint source management measures are also established. These milestones provide a general framework to track progress of watershed implementations geared toward improving water quality. An effectiveness monitoring plan was also developed and is included in the implementation plan. Strategies presented in the implementation plan for reducing nonpoint sources are recommendations and serve only to act as a guideline for stakeholders interested in reducing *E. coli* loads to surface waters.

CONTENTS

APPENDICES

FIGURES

TABLES

GLOSSARY AND ABBREVIATIONS

°C	degrees Celsius
AUE	animal unit equivalent
BLM	Bureau of Land Management
BMP	best management practices
BOR	Bureau of Reclamation
BSLC	bacteria source load calculator
cfu	colony forming unit
E. coli	*Escherichia coli*
EPA	U.S. Environmental Protection Agency
G-cfu	giga colony forming unit (defined as 10^9 colony forming units of bacteria)
LA	load allocation
MGD	million gallons per day
mL	milliliters
MOS	margin of safety
MPN	most probable number
NHD	National Hydrography Dataset
SEO	Wyoming State Engineer's Office
Subirrigation	As defined by the Wyoming Water Development Commission, these are lands that appear to be receiving irrigation water based on aerial imagery analysis but have no appropriated water right.
SWCA	SWCA Environmental Consultants
TMDL	total maximum daily load
UCCD	Uinta County Conservation District
UDEQ	Utah Department of Environmental Quality
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
WDEQ	Wyoming Department of Environmental Quality
WGFD	Wyoming Game and Fish Department
WLA	wasteload allocation
WQD	Water Quality Division
WWDC	Wyoming Water Development Commission
WWTP	wastewater treatment plants
WYPDES	Wyoming Pollutant Discharge Elimination System

1. INTRODUCTION

1.1. Purpose

This document represents the total maximum daily load (TMDL) analyses of four impaired reaches of the Blacks Fork and Smiths Fork Rivers within the greater Blacks Fork Watershed in fulfillment of Clean Water Act (CWA) requirements.

A TMDL analysis determines the amount of an identified pollutant (i.e., the load) that a waterbody can receive while preserving its designated uses and state water quality standards. Once the pollutant loads have been identified, controls are implemented to reduce those loads until the waterbody is brought back into compliance with water quality standards. Upon completion of the TMDL analysis, it is submitted to the Wyoming Department of Environmental Quality (WDEQ) and the U.S. Environmental Protection Agency (EPA) for approval.

The Federal Water Pollution Control Act is the primary federal legislation that protects surface waters such as lakes and rivers. This legislation, originally enacted in 1948, was expanded in 1972 and became known as the CWA. The purpose of the CWA is to improve and protect the physical, chemical, and biological integrity of the nation's waters. The CWA requires EPA or delegated authorities such as states, tribes, and territories to evaluate the quality of waters, establish beneficial uses, and define water quality criteria to protect those uses. Section 303(d) of the CWA requires that, every 2 years, each state submit a list of waterbodies that fail state water quality standards to the EPA. This list is the "303(d) list," and waterbodies identified on the list are referred to as "impaired waters." For impaired waters, the CWA requires a TMDL analysis for each pollutant responsible for impairment of its designated use(s).

WDEQ's Water Quality Division (WQD) collects biological and water quality data to evaluate the quality of the waters of the State of Wyoming. Based on this assessment, Blacks Fork and Smiths Fork Rivers were included on the State of Wyoming's 303(d) list in 2000 for exceedances in *Escherichia coli* (*E. coli*) and fecal coliform. This report defines the TMDL and water quality targets that, when attained, will bring impaired reaches of the Blacks Fork and Smiths Fork Rivers into full support of the uses designated by the State of Wyoming.

1.2. Problem Statement

An assessment of water quality conducted by the WDEQ resulted in the Blacks Fork and Smiths Fork Rivers in Wyoming being listed as impaired due to violations of the *E. coli* standard. *E. coli* is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals and is considered the best indicator of human health risk in surface waters (EPA 2012).

These violations have the potential to affect watershed residents because the Blacks Fork and Smiths Fork Rivers are extensively used for irrigation, recreation, and fishing. Impairment of waterbodies in the Blacks Fork Watershed is cause for concern because of the potential human health risk, degradation of aquatic life, and implications for future management of agricultural practices and local communities. Common sources of *E. coli* include waste from livestock and wildlife as well as input from faulty septic systems. In more urban areas with high degrees of impervious surface, pet waste runoff can also become a significant source.

1.3. Designated Uses and Associated Water Quality Standards

Protection of waters under the CWA consists of three main components: 1) designating uses, 2) establishing water quality criteria to protect those uses, and 3) developing and applying antidegradation policies and procedures.

The State of Wyoming has designated surface water uses, water quality criteria to protect those uses, and antidegradation policies and procedures in *Water Quality Rules and Regulations Chapter 1, Wyoming Surface Water Quality Standards* (hereafter Wyoming's surface water quality standards; WDEQ 2013a). Section 2(b)(ix) of the surface water quality standards defines *designated uses* as "those uses specified in water quality standards for each water body or segment whether or not they are being attained" (WDEQ 2013a:1-3). The designated uses that are protected for Wyoming's surface waters are listed and described in Section 3 of the surface water quality standards and include agriculture, fisheries, industry, drinking water, recreation, scenic value, aquatic life other than fish, wildlife, and fish consumption. These uses are defined in Wyoming's surface water quality standards as follows (WDEQ 2013a:1-8–1-9):

> (a) Agriculture. For purposes of water pollution control, agricultural uses include irrigation and/or livestock watering.
>
> (b) Fisheries. The fisheries use includes water quality, habitat conditions, spawning and nursery areas, and food sources necessary to sustain populations of cold water game fish, warm water game fish and nongame fish. This use does not include the protection of aquatic invasive species or other fish which may be considered "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service within their appropriate jurisdictions.
>
> (c) Industry. Industrial use protection involves maintaining a level of water quality useful for industrial purposes.
>
> (d) Drinking water. The drinking water use involves maintaining a level of water quality that is suitable for potable water or intended to be suitable after receiving conventional drinking water treatment.
>
> (e) Recreation. Recreational use protection involves maintaining a level of water quality which is safe for human contact. It does not guarantee the availability of water for any recreational purpose. The recreation designated use includes primary contact recreation and secondary contact recreation subcategories.
>
> (f) Scenic value. Scenic value use involves the aesthetics of the aquatic systems themselves (odor, color, taste, settleable solids, floating solids, suspended solids and solid waste) and is not necessarily related to general landscape appearance.
>
> (g) Aquatic life other than fish. This use includes water quality and habitat necessary to sustain populations of organisms other than fish in proportions which make up diverse aquatic communities common to the waters of the state. This use does not include the protection of human pathogens, insect pests, aquatic invasive species or other organisms which may be considered "undesirable" by the Wyoming Game and Fish Department or the U.S. Fish and Wildlife Service within their appropriate jurisdictions.
>
> (h) Wildlife. The wildlife use includes protection of water quality to a level which is safe for contact and consumption by avian and terrestrial wildlife species.
>
> (i) Fish consumption. The fish consumption use involves maintaining a level of water quality that will prevent any unpalatable flavor and/or accumulation of harmful substances in fish tissue.

Wyoming's surface waters are classified according to their designated uses using a hierarchical system described in Wyoming's surface water quality standards (WDEQ 2013a). There are four major classes of surface water in Wyoming with various subcategories within each class. Waters are placed into Classes 1–4 (Table 1.1) based on their designated uses, with Class 1 waters being managed for the highest water quality and Class 4 waters being managed for the lowest water quality. Table 1.1 provides a summary of Wyoming's surface water classifications (far left column) and associated designated uses (top row). For each surface water class, a "Yes" indicates that a designated use is protected for that class, whereas a "No" indicates that the use is not protected for that class (WDEQ 2013b).

Table 1.1. Wyoming's Surface Water Classes and Designated Uses

Class	Drinking Water	Game Fish	Non-Game Fish	Fish Consumption	Other Aquatic Life	Recreation	Wildlife	Agriculture	Industry	Scenic Value
1*	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2AB	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2A	Yes	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
2B	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2C	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2D	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
3A	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3B	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3C	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
3D	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
4A	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4B	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes
4C	No	No	No	No	No	Yes	Yes	Yes	Yes	Yes

Source: WDEQ (2013b).

Notes: "Yes" indicates the use is protected for that water class, whereas "No" indicates that it is not protected for that water class.

* Class 1 waters are not protected for all uses in all circumstances. For example, all waters in the national parks and wilderness areas are Class 1; however, all do not support fisheries or other aquatic life uses (e.g., hot springs, ephemeral waters, wet meadows; WDEQ 2013b).

The State of Wyoming has classified the Blacks Fork and Smiths Fork Rivers as Class 2AB waterbodies. Waters classified as Class 2AB are defined by the WDEQ as follows in the Wyoming surface water quality standards:

> Class 2AB waters are those known to support game fish populations or spawning and nursery areas at least seasonally and all their perennial tributaries and adjacent wetlands and where a game fishery and drinking water use is otherwise attainable. Class 2AB waters include all permanent and seasonal game fisheries and can be either "cold water" or "warm water" depending upon the predominance of cold water or warm water species present. All Class 2AB waters are designated as cold water game fisheries unless identified as a warm water game fishery by a "ww" notation in the *Wyoming Surface Water Classification List*. Unless it is shown otherwise, these waters are presumed to have sufficient water quality and quantity to support drinking water supplies and are protected for that use. Class 2AB waters are also protected for nongame fisheries, fish consumption, aquatic life other than fish, recreation, wildlife, industry, agriculture and scenic value uses. (WDEQ 2013a:1-10).

Section 305(b) of the CWA requires states to describe the water quality condition of all their waters and determine whether these waters support their designated uses. As stated in the *Wyoming Water Quality Assessment and Impaired Waters List (2012 Integrated 305(b) and 303(d) Report)* (hereafter the integrated report; WDEQ 2012), Wyoming's Watershed Monitoring Program is responsible for providing most of the information used in determining whether designated uses are supported for the surface waters of the state; however, other groups (e.g., the U.S. Geological Survey [USGS] and Wyoming's 34 conservation districts) also contribute substantially. These data are used to determine water quality condition following methods outlined in *Wyoming's Method for Determining Water Quality Condition of Surface Waters and TMDL Prioritization Criteria for 303(d) Listed Waters* (WDEQ 2013c). This methodology is revised periodically to maintain consistency with changes in the state's water quality standards and to comply with Wyoming's "Credible Data" Law.

Generally, a water is deemed to be non-supporting of one or more designated uses (i.e., impaired) if any narrative or numeric criteria are exceeded, or if designated uses are shown to be adversely affected by anthropological activities (WDEQ 2013c). Wyoming's integrated report (WDEQ 2012) lists reaches of the Blacks Fork and Smiths Fork Rivers as not supporting their designated uses due to violation of the *E. coli* standard, and these reaches were added to the 303(d) list in 2000.

The second component of the protection of waters under the CWA is the establishment of water quality criteria to protect designated uses. Wyoming's water quality standards applicable to Blacks Fork/Smiths Fork impairment consist of numeric limits for *E. coli* concentrations (Table 1.2). These standards are designed to prevent *E. coli* from exceeding quantities that would impair designated uses.

Table 1.2. Surface Water Quality Standards for *E. coli* Applicable to the Designated Uses in the Blacks Fork Watershed

Parameter	Water Quality Standard Reference	Standard/Description
E. coli Bacteria*	Section 27	(a) Primary Contact Recreation. In all waters designated for primary contact recreation, during the summer recreation season (May 1–September 30), concentrations of *E. coli* bacteria shall not exceed a geometric mean of 126 organisms per 100 milliliters based on a minimum of not less than five samples obtained during separate 24-hour periods for any 60-day period. All waters in Table A of the Wyoming Surface Water Classification List are designated for primary contact recreation unless identified as a secondary contact water by a "(s)" notation. Waters not specifically listed in Table A of the Wyoming Surface Water Classification List shall be designated as secondary contact waters. During the period of October 1 through April 30, all waters are protected for secondary contact recreation only. (b) Secondary Contact Recreation. In all waters designated for secondary contact recreation, and in waters designated for primary contact recreation during the winter recreation season (October 1–April 30), concentrations of *E. coli* bacteria shall not exceed a geometric mean of 630 organisms per 100 milliliters based on a minimum of not less than five samples obtained during separate 24-hour periods for any 60-day period. (c) Single-sample Maximum Concentrations. During the summer recreation season, on all waters designated for primary contact recreation, the following single-sample maximum concentrations of *E. coli* bacteria shall apply: (i) High-use swimming areas: 235 organisms per 100 milliliters (ii) Moderate full-body contact: 298 organisms per 100 milliliters (iii) Lightly used full-body contact: 410 organisms per 100 milliliters (iv) Infrequently used full-body contact: 576 organisms per 100 milliliters Single-sample maximum values may be used to post recreational use advisories in public recreation areas and to derive single-sample maximum effluent limitations on point source discharges. An exceedance of the single-sample maxima shall not be cause for listing a waterbody on the State 303(d) list or development of a TMDL or watershed plan. The appropriate recreational use category (i through iv above) shall be determined by the administrator as needed, on a case by case basis. In making such a determination, the administrator may consider such site-specific circumstances as type and frequency of use, time of year, public access, proximity to populated areas, and local interests.

Source: WDEQ (2007).

* Original impairments were based on the former fecal coliform bacteria standard listed in WDEQ 2001b.

The third component for the protection of waters under the CWA consists of antidegradation policies and procedures. Wyoming's Antidegradation Policy, described in Section 8 of Wyoming's surface water quality standards (WDEQ 2013a:1-14–1-15) states the following:

> Water uses in existence on or after November 28, 1975 and the level of water quality necessary to protect those uses shall be maintained and protected. Those surface waters not designated as Class 1, but whose quality is better than the standards contained in these regulations, shall be maintained at that higher quality. However, after full intergovernmental coordination and public participation, the department may issue a permit for or allow any project or development which would constitute a new source of pollution, or an increased source of pollution, to these waters as long as the following conditions are met:
>
> (i) The quality is not lowered below these standards;
>
> (ii) All existing water uses are fully maintained and protected;
>
> (iii) The highest statutory and regulatory requirements for all new and existing point sources and all cost effective and reasonable best management practices for nonpoint sources have been achieved; and
>
> (iv) The lowered water quality is necessary to accommodate important economic or social development in the area in which the waters are located.
>
> (b) The Water Quality Administrator (administrator) may require an applicant to submit additional information, including, but not limited to, an analysis of alternatives to any proposed discharge and relevant economic information before making a determination under this section.
>
> (c) The procedures used to implement this section are described in the *Antidegradation Implementation Policy*.

1.4. Impaired Waters

Impaired reaches in the Blacks Fork Watershed are summarized in Table 1.3 and Figure 1.1. The following reach-specific impairments (Figure 1) have been identified (WDEQ 2012; Uinta County Conservation District [UCCD] 2005):

- Blacks Fork from Smiths Fork upstream to Millburne (Reach 1); fecal coliform impairment (converted to *E. coli*)
- Blacks Fork from Hams Fork upstream to Smiths Fork (Reach 2); *E. coli* impairment
- Smiths Fork from Blacks Fork upstream to Cottonwood Creek (Reach 3); *E. coli* impairment
- Smiths Fork from Cottonwood Creek upstream to the East Fork and West Fork of Smiths Fork (Reach 4); fecal coliform impairment (converted to *E. coli*)

Original impairment listings for Reach 1 and Reach 4 were based on the fecal coliform standard that stated that the geometric mean (hereafter geomean) of five samples should not exceed 200 organisms per 100 mL obtained during separate 24 hour periods within a 30 day time span, however this standard was changed to the present *E. coli* standard in 2007 (WDEQ 2007). As such, TMDL development is structured around *E. coli* data only. It should also be noted that more recent data collected from Reach 2 shows that an impairment no longer exists, however Reach 2 was still considered in the source analysis.

Table 1.3. Impaired Reach Description from Wyoming's 2012 Integrated 305(b) and 303(d)

Name	Class	Location	Miles	Uses	Use Support	Causes	List Date
Reach 1	2AB	Blacks Fork from Smiths Fork upstream to Millburne	27	Recreation	Not supporting	Fecal coliform impairment (converted to *E. coli*)	2000
Reach 2*	2AB	Blacks Fork from Hams Fork upstream to Smiths Fork	79	Recreation	Not supporting	*E. coli*	2000
Reach 3	2AB	Smiths Fork from Blacks Fork upstream to Cottonwood Creek	4	Recreation	Not supporting	*E. coli*	2000
Reach 4	2AB	Smiths Fork from Cottonwood Creek upstream to the East Fork and West Fork of Smiths Fork	35	Recreation	Not supporting	Fecal coliform impairment (converted to *E. coli*)	2000

* Reach 2 is not currently impaired; however, it has not been officially delisted and therefore still maintains a "not supporting" designation.

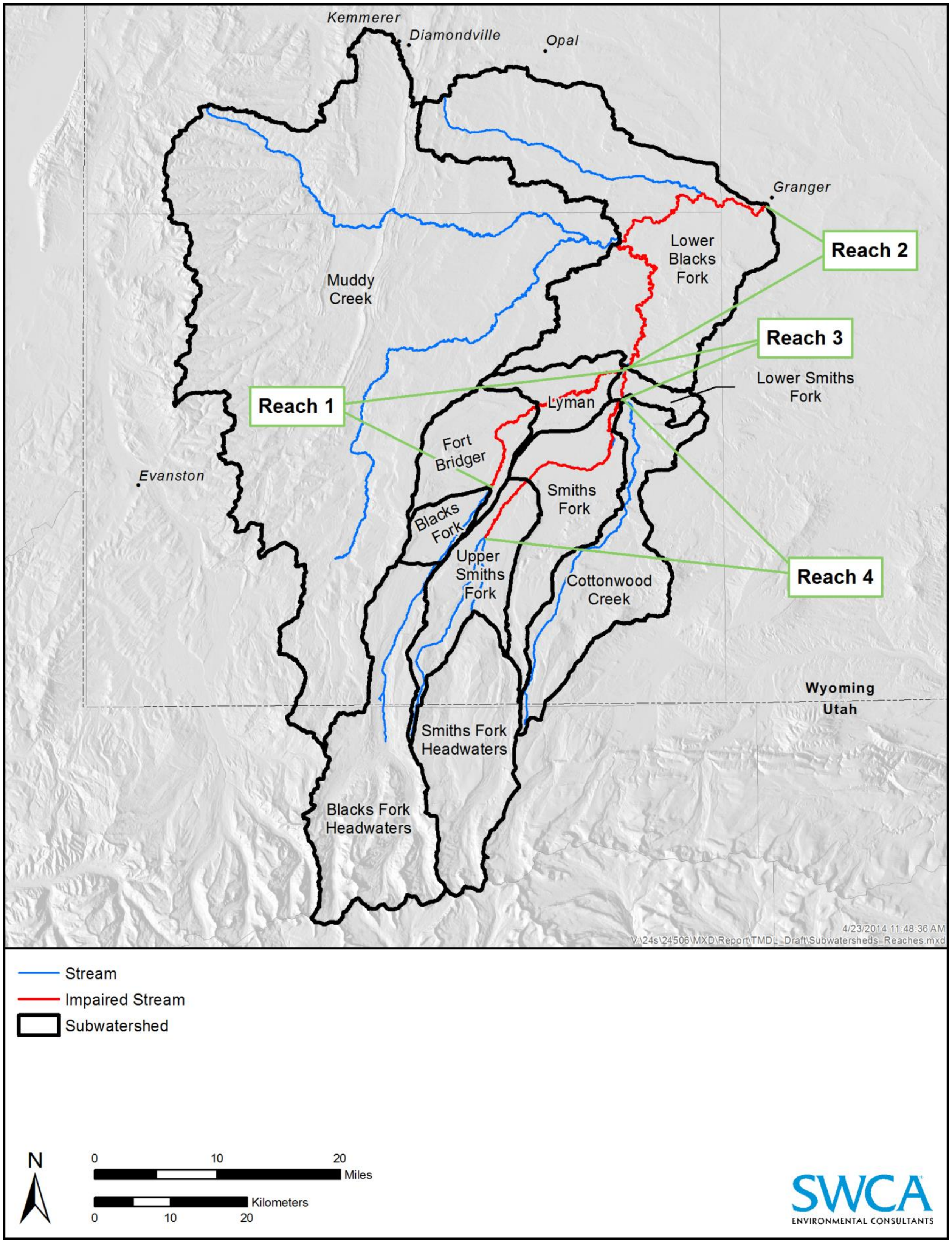

Figure 1.1. Locations of impaired reaches along the Blacks Fork River and Smiths Fork Rivers.

1.4.1. Study Area Boundaries

For purposes of TMDL development, the study area is the *Blacks Fork Watershed*. It refers to the drainage area upstream of the confluence of Blacks Fork with Hams Fork and has been divided into eleven subwatersheds (Figure 1.2). Subwatersheds in the Blacks Fork Watershed were delineated to calculate *E. coli* loads into and out of different areas of the watershed; they include subwatersheds that are not currently listed as impaired. Including these subwatersheds in the TMDL analysis is important for understanding and accounting for upstream *E. coli* loading. Subwatershed boundaries were identified based on breaks in the 303(d) listings of impaired reaches, changes in land use, location of hydrological nodes (see section 3.5.4.1), location of water quality monitoring sites (see section 3.6.1), and the availability of *E. coli* data (Figure 1.2). Table 1.4 lists the 11 subwatersheds and corresponding model node and water quality site selected to calculate loads. In the case of the Muddy Creek subwatershed, no water quality data were available; therefore, data from the Cottonwood Creek subwatershed were applied because that subwatershed is comparable with regard to land use characteristics. A similar approach was used for the Smiths Fork Headwaters subwatershed where water quality data from the Blacks Fork Headwaters subwatershed were applied. The subwatershed scale facilitates a targeted analysis of sources and contributes to a more meaningful implementation plan that is based on prioritization of best management practices (BMPs).

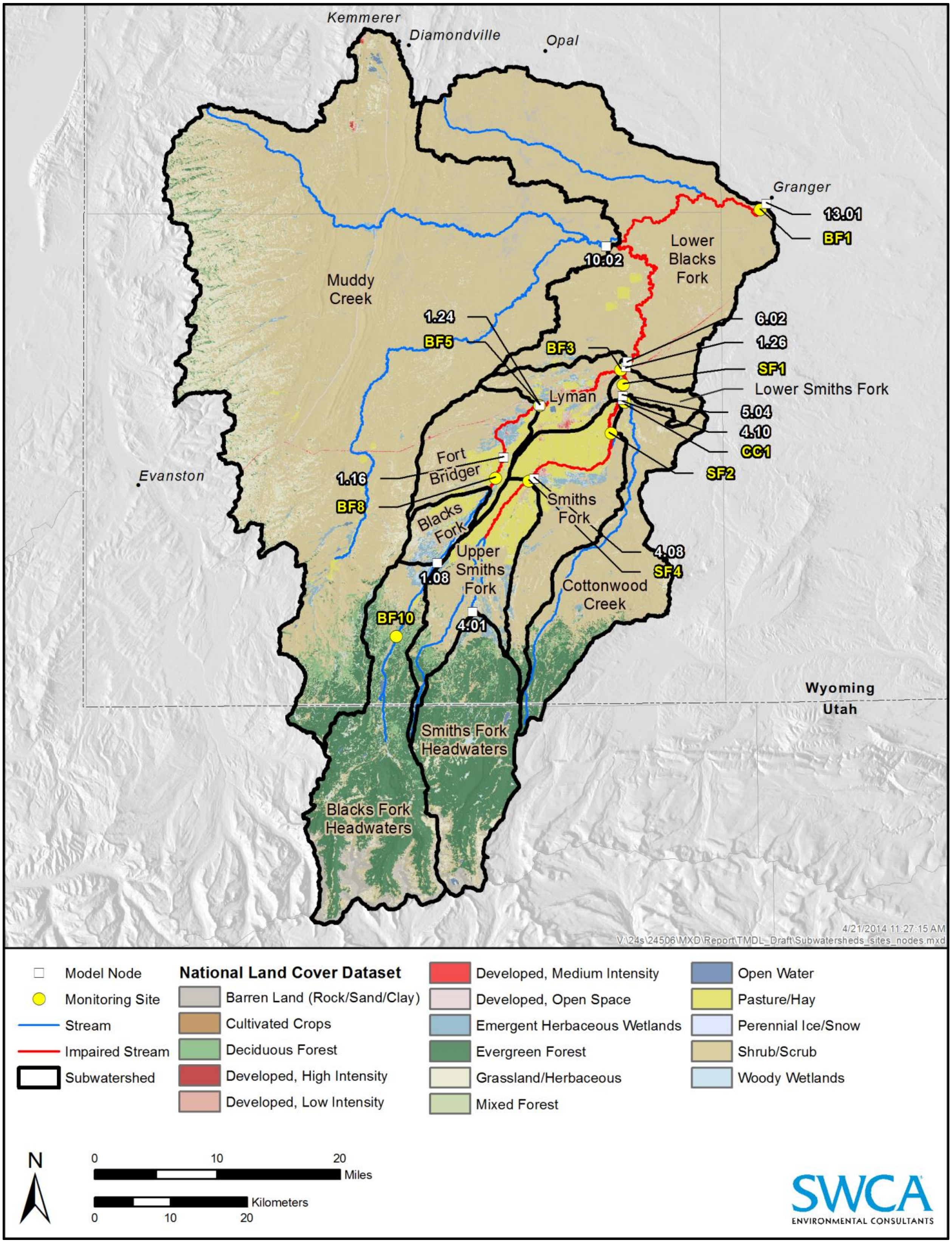

Figure 1.2. Subwatershed boundaries and corresponding model nodes and water quality sites used to generate loads.

Table 1.4. Subwatersheds in the Blacks Fork Watershed used in Total Maximum Daily Load Development and their Associated Blacks Fork Basin Model Node and Uinta County Conservation District Water Quality Monitoring Site

Reach	Subwatershed	Miles	Model Node	Monitoring Site
Not impaired	Muddy Creek	75	10.02	CC1*
2	Lower Blacks Fork	45	13.01	BF1
1	Lyman	14	1.26	BF3
1	Fort Bridger	13	1.24	BF5
Not impaired	Blacks Fork	9	1.16	BF8
Not impaired	Blacks Fork Headwaters	18	1.08	BF10
3	Lower Smiths Fork	4	6.02	SF1
Not impaired	Cottonwood Creek	38	5.04	CC1
4	Smiths Fork	19	4.10	SF2
4	Upper Smiths Fork	16	4.08	SF4
Not impaired	Smiths Fork Headwaters	30	4.01	BF10*

* In the case of the Muddy Creek subwatershed, no water quality data were available; therefore, data from the Cottonwood Creek subwatershed were applied because that subwatershed is comparable with regard to land use characteristics. A similar approach was used for the Smiths Fork Headwaters subwatershed where water quality data from the Blacks Fork Headwaters subwatershed were applied.

1.5. History of Watershed Planning in Blacks Fork Watershed

Extensive work toward understanding the Blacks Fork Watershed and improving water quality in stream reaches has been conducted over the past several years, paving the way for a more defensible and adaptable TMDL. Several scientific and resource management reports have been written by local, state, and federal agencies that provide data and information pertinent to the TMDL process. Some reports provide background data on the setting and general conditions of the Blacks Fork Watershed, whereas other reports provided pertinent information on past watershed management efforts and surface water hydrology and water quality. All relevant information was incorporated into the TMDL analysis and referenced appropriately (Table 1.5).

Table 1.5. Summary of Reports and Studies Relevant to the Blacks Fork and Smiths Fork Total Maximum Daily Loads Analysis and Implementation Planning

Topic	Year	Title	Author	Summary of Key Findings Relevant to TMDL Analysis
Surface water hydrology	2010	*2010 Green River Basin Water Plan Final Report*	Wyoming Water Development Commission (WWDC)	This report includes information about water use and water supply in the basin in addition to general watershed characteristics.
Surface water hydrology	2010	*Technical Memorandum: Green River Basin Plan II Task 3A-Surface Water Data Collection and Study Period Selection*	WWDC	This memorandum explains how portions of the model were developed. It explains how years were classified into wet, dry, and average years and what determined "wet," "dry," or "average." It also includes a brief literature review relating to climatic and hydrologic conditions in the Green River Basin.
Water quality	2008	Blacks Fork/Smiths Fork Water Quality Project	UCCD (personal communication, PowerPoint presentation [ftp upload] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA Environmental Consultants [SWCA], April 29, 2013)	This is a PowerPoint slideshow discussing water quality issues in Blacks Fork and Smiths Fork.
Watershed management	2005	*Blacks Fork and Smiths Fork Rivers Watershed Management Plan*	Blacks Fork/Smiths Fork Water Quality Steering Committee, UCCD	This is a comprehensive natural resource management plan with a focus on addressing water quality issues. It contains general information about the Blacks Fork Watershed, identifies specific watershed and water quality concerns, and lists specific actions to take to address concerns.
Water quality	2003	*Monitoring and Assessment Report*	WDEQ WQD (personal communication, *Monitoring and Assessment Report* [ftp upload] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA, April 29, 2013)	This is a water quality assessment report for Blacks Fork. It includes a watershed description and relevant information on potential sources and influence of geology and soils on water quality.
Water quality	unknown	*Beneficial Use Reconnaissance Monitoring and Assessment Report*	WDEQ WQD (personal communication, *Beneficial Use Reconnaissance Monitoring and Assessment Report* [ftp upload] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA, April 29, 2013)	Specific to Smiths Fork, this report includes macroinvertebrate sampling data and assessment of beneficial use attainment. This is primarily a data report that looks at habitat quality on Smiths Fork.
Water quality	2003	*Monitoring and Assessment Report*	WDEQ WQD (personal communication, *Monitoring And Assessment Report* [ftp upload] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA, April 29, 2013)	This report is a water quality assessment for Smiths Fork and Smiths Fork tributaries.
Water quality	2009, 2011	Stream Water Quality Data Analysis	WWC Engineering (personal communication, stream water quality data analysis memoranda [ftp upload] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA, April 29, 2013)	These two technical memoranda summarize the water quality data that the UCCD collected from 2007 to 2008 (report in 2009) and from 2009 to 2010 (report in 2011).
Hydrology/Irrigation	2012	*2012 Wyoming Irrigation Systems Report*	WWDC	This report provides tables of information about irrigation, including irrigation company names, the water rights held, amount of irrigated lands, and amount of reservoir storage.

Table 1.5. Summary of Reports and Studies Relevant to the Blacks Fork and Smiths Fork Total Maximum Daily Loads Analysis and Implementation Planning

Topic	Year	Title	Author	Summary of Key Findings Relevant to TMDL Analysis
Recreation/Fisheries	2008	Fishing Utah: An Anglers Guide to More Than 170 Prime Fishing Spots	Brett Prettyman	This is a fishing guide that describes areas considered fisheries in the Uinta portions of the Blacks Fork and Smiths Fork drainages.
Fisheries	1996, 2004	Regional Aquatic Wildlife Management Annual Progress Report	Green River Regional Fisheries Management Crew (personal communication, *Regional Aquatic Wildlife Management Annual Progress Report* [emailed] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA, July 2, 2013)	These reports (one from 1996 and one from 2004) present the results of fisheries sampling in Smiths Fork watershed, specifically Willow Creek.
Fisheries	2005	2004 Progress Report: Green River Watershed Native Non-Game Fish Species Research: Phase II	Wyoming Game and Fish Department (personal communication, *2004 Progress Report: Green River Watershed Native Non-game Fish Species Research* [emailed] from Brianna Forrest, WDEQ, to Erica Gaddis, SWCA, July 2, 2013)	This report documents efforts completed in 2004 to protect fish species native to the Colorado River basin. The 2004 efforts are part of a multi-year effort that began in 2002 and focuses on Green River basin streams.
Resource management	2003	Uinta National Forest 2003 Land Resource Management Plan Revision	U.S. Forest Service, Uinta National Forest	This is a resource management plan for the areas that the U.S. Forest Service owns and manages.

2. REGIONAL SETTING

2.1. History

The Blacks Fork and Smiths Fork Rivers originate high in the Uinta Mountains of Utah and flow north descending through coniferous forests and mountainous terrain before reaching the lowlands of the Bridger Valley. From there, the rivers join and continue on a northeasterly course to their confluence with Hams Fork and eventual termination in Flaming Gorge Reservoir. The lowlands of the Bridger Valley are dominated primarily by grasslands and sagebrush communities; however, much of the landscape has been converted to crop and pastureland for agricultural use and livestock grazing. Historically, the valley served as a major byway for the California/Oregon Trail, the Pony Express, the Transcontinental Railroad, and the Lincoln Highway, and as a result, several towns were developed to serve the needs of travelers (Wyoming Office of Tourism 2014). Incorporated towns in the valley include Fort Bridger, Lyman, and Mountain View.

The town of Fort Bridger was established in 1842 by explorer Jim Bridger and his partner Louis Vasquez and served as a major hub for trading activities between fur trappers, Native Americans, and mountain men. Today, the town conducts an annual Fort Bridger Rendezvous to celebrate the rich history of trading and Native American culture in the region. The original fort location is now a Wyoming state park that contains a group of well-preserved structures and a museum. In addition to cultural history, Fort Bridger along with Lyman and Mountain View also serve as the "Gateway to the High Uintas," which offers tourists and recreationalists access to the rugged Uinta Peaks, Uinta-Wasatch-Cache National Forest, and Flaming Gorge Reservoir where fishing, hiking, and camping opportunities abound (Town of Mountain View 2013).

2.2. Population and Growth

The Blacks Fork Watershed is 1,343,732 acres, 67% of which is in Uinta County, Wyoming. As of the 2010 census (U.S. Census Bureau 2010), the population of Uinta County, Wyoming, was 21,118. Understanding future population growth at the watershed scale requires an examination of both countywide projected population estimates and historical population growth for the towns of Lyman, Mountain View, and Fort Bridger. Future population growth for these three towns was estimated using census data from 2000 and 2010 (U.S. Census Bureau 2010). Lyman and Mountain View were found to increase by approximately 7% and 9%, respectively. An increase of a similar magnitude was assumed for Fort Bridger (8%) because no historical or future population data exist. Future populations for each town are shown in Table 2.1 in addition to estimated growth for Uinta County and the state of Wyoming. Between 2010 and 2030, the population of Wyoming is estimated to increase by 19%, whereas Uinta County is estimated to increase by 11%. Much of the increase in population growth in Uinta County is expected to occur in more rural areas of the county, particularly in the mountainous headwaters regions.

Table 2.1. Projected Population Growth for Wyoming and the Blacks Fork Watershed

	Population 2010	Estimated Population 2020	Estimated Population 2030
Wyoming	563,626	622,360	668,830
Uinta County	21,118	22,580	23,440
Lyman	2,115	2,263	2,421
Mountain View	1,286	1,402	1,528
Fort Bridger	345	373	402

Note: Based on a 7%, 8%, and 9% increase in population for Lyman, Fort Bridger, and Mountain View.

Source: Wyoming Department of Administration and Information: Economic Analysis Division (2011).

2.3. Climate

The hydrologic characteristics of the Blacks Fork Watershed are typical of stream systems in the Green River Basin in that they have a predominantly snowmelt- and groundwater-driven hydrologic system, with peak flows occurring in late May and early June. Baseflow conditions typically extend from late fall through winter. Two weather stations are in the Blacks Fork Watershed: Church Butte Gas Platform and Mountain View (Figure 2.1 and Table 2.2). The Church Butte station is near the eastern watershed boundary, whereas the Mountain View station is in the town toward the middle of the watershed. Data from these stations show that temperatures vary widely by season. Average minimum temperatures are below freezing in the winter months, and average maximum temperatures approach 30 degrees Celsius (°C) in the summer months (Tables 2.3 and 2.4). Snowfall is the dominant form of precipitation, but amounts vary with elevation and location within the watershed (see Tables 2.3 and 2.4). Additionally, on average, this area experiences 72 rain days and 24 snow days a year (CLR Search 2012).

Table 2.2. Weather Stations in the Blacks Fork Watershed

Weather Station Name	Weather Station ID Number	Latitude	Longitude	Elevation (feet)	Period of Record Available	Subwatersheds
Church Buttes Gas Platform	USC00481736	41.398	-110.086	7,075.13	November 1955 to present	Lower Blacks Fork
Mountain View	USC00486555	41.271	-110.331	6,799.87	March 1966 to present	Smiths Fork

Source: Utah State University Climate Center (2013).

Table 2.3. Climate Summary for Church Butte Gas Platform Weather Station

Month	Average Minimum Temperature (°C)	Average Maximum Temperature (°C)	Average Total Precipitation (millimeters)	Average Total Snowfall (millimeters)
January	-10.86	0.16	0.29	2.93
February	-10.79	0.20	0.28	3.31
March	-5.82	6.05	0.29	2.27
April	-2.77	11.44	0.71	1.83
May	2.69	17.64	0.87	1.85
June	7.43	23.67	0.81	0.00
July	13.02	29.22	0.49	0.00
August	11.65	27.43	0.63	0.00
September	6.17	21.62	0.89	0.43
October	-0.19	13.69	0.61	0.45
November	-6.12	5.01	0.29	2.73
December	-11.06	-0.33	0.25	2.86
Monthly average	**-0.55**	12.98	0.53	1.55
Annual total	**N/A**	**N/A**	**6.42**	**18.66**

Source: Utah State University Climate Center (2013).

Note: N/A = not applicable.

Table 2.4. Climate Summary for Mountain View Weather Station

Month	Average Minimum Temperature (°C)	Average Maximum Temperature (°C)	Average Total Precipitation (millimeters)	Average Total Snowfall (millimeters)
January	-10.18	1.00	0.43	7.25
February	-10.17	1.45	0.51	9.55
March	-5.89	7.10	0.61	9.21
April	-2.39	12.68	1.13	7.95
May	1.62	17.94	1.17	4.26
June	5.46	22.98	0.99	0.19
July	10.03	27.96	0.95	0.00
August	8.72	26.63	0.77	0.00
September	4.08	21.94	0.97	0.75
October	-0.76	14.73	0.83	4.34
November	-6.70	6.20	0.65	8.03
December	-10.28	0.69	0.73	9.18
Monthly average	-1.37	13.44	0.81	5.06
Annual total	**N/A**	**N/A**	**9.75**	**60.70**

Source: Utah State University Climate Center (2013).

Note: N/A = not applicable.

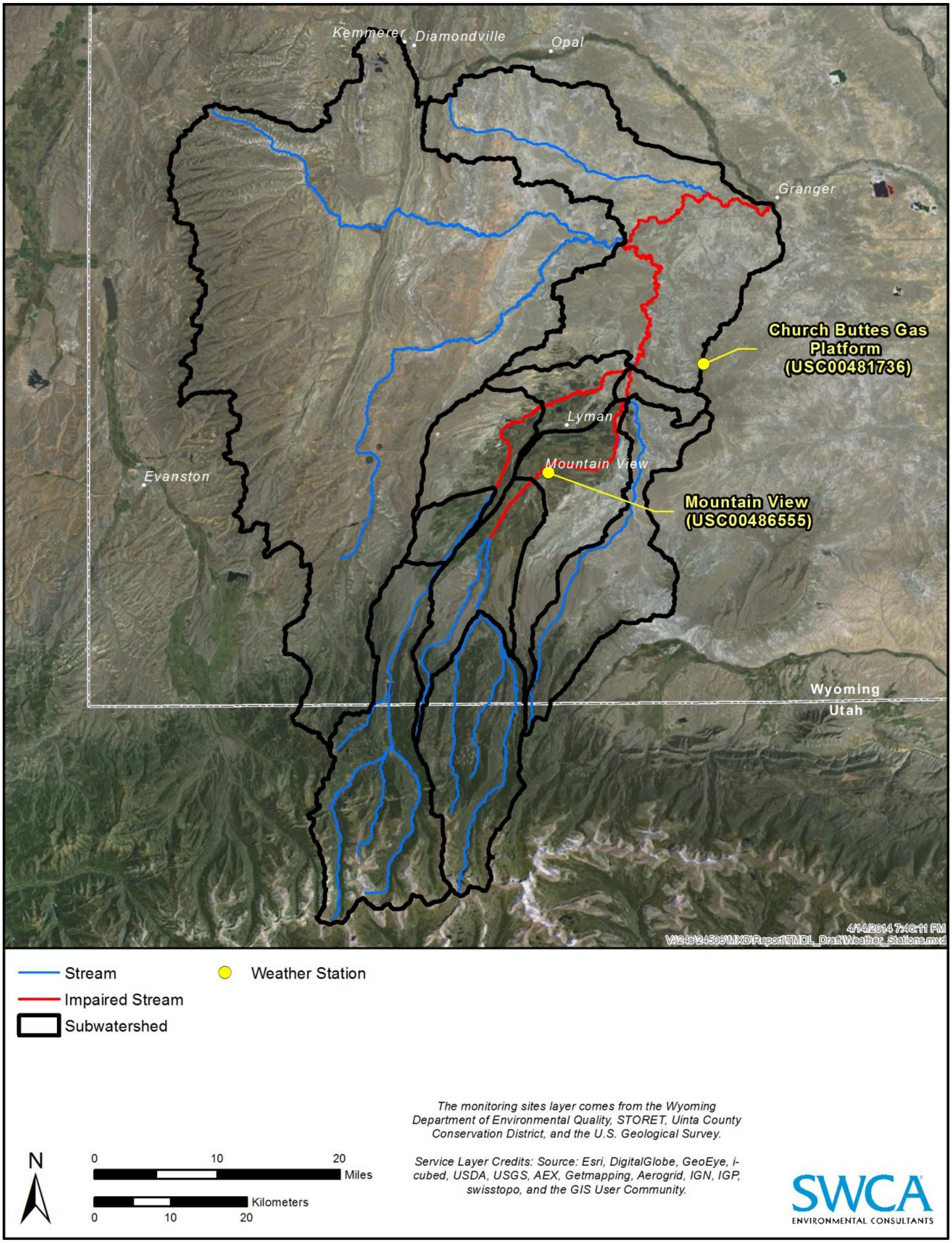

Figure 2.1. Weather stations in the Blacks Fork Watershed**.**

3. WATERSHED CHARACTERIZATION

3.1. Landownership

Understanding landownership patterns in the Blacks Fork Watershed is important for developing implementation strategies that are appropriate for the region in question. In the Blacks Fork region, landownership is equally portioned between private and federal ownership with a small amount of state-owned lands (Table 3.1). Federal ownership is primarily by the Bureau of Land Management (BLM); however, the U.S. Forest Service (USFS) owns large tracts in the headwaters regions as a part of the Uinta-Wasatch-Cache-National Forest. Generally speaking, the inner subwatersheds (Blacks Fork, Fort Bridger, and Lyman) tend to have more privately owned land compared to the outer subwatersheds (Cottonwood Creek, Blacks Fork Headwaters, and Smiths Fork Headwaters), which are mostly federally owned (Figure 3.1).

Table 3.1. Land Ownership in the Blacks Fork Watershed

Subwatershed	Acres					Percentage of Acres			
	Private	Federal	State	Open Water	Total	Private	Federal	State	Open Water
Blacks Fork Headwaters	22,243	97,921	1,587	493	122,244	18%	80%	1%	> 1%
Blacks Fork	15,321	634	0	0	15,955	96%	4%	0%	0%
Fort Bridger	29,577	14,117	0	175	43,869	67%	32%	0%	> 1%
Lyman	17,487	8,906	388	159	26,940	65%	33%	1%	1%
Smiths Fork Headwaters	8,474	76,366	1,284	0	86,124	10%	89%	1%	0%
Upper Smiths Fork	32,704	17,042	1,301	40	51,087	64%	33%	3%	> 1%
Smiths Fork	33,029	31,498	0	107	64,634	51%	49%	0%	> 1%
Cottonwood Creek	16,449	67,260	620	44	84,373	19%	80%	1%	> 1%
Lower Smiths Fork	2,513	7,701	14	0	10,228	25%	75%	0%	0%
Muddy Creek	344,627	241,915	24,838	438	611,818	56%	40%	4%	> 1%
Lower Blacks Fork	117,176	99,555	9,448	281	226,460	52%	44%	4%	> 1%
Total	639,600	662,915	39,480	1,737	1,343,732	48%	49%	3%	> 1%

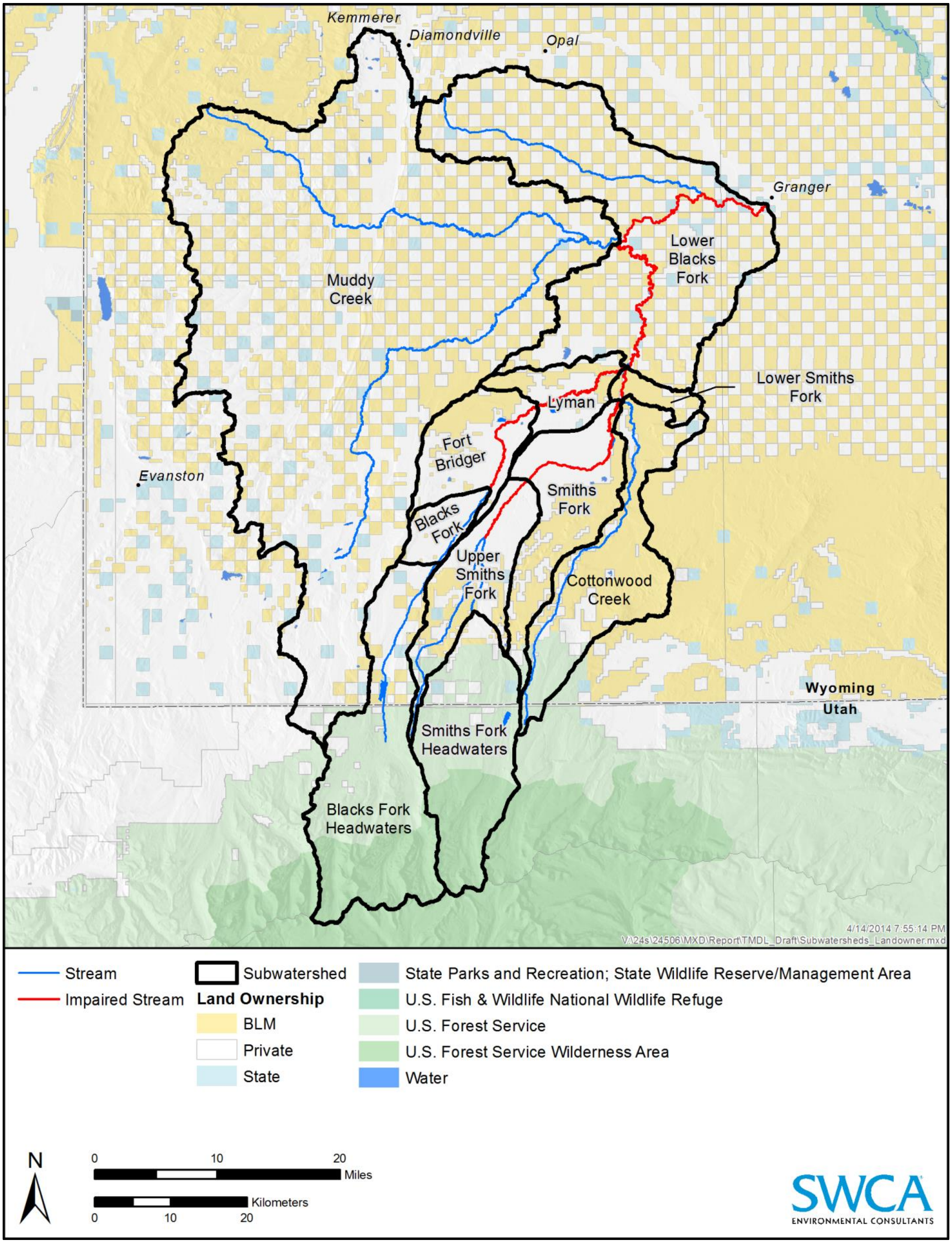

Figure 3.1. Landownership in the Blacks Fork Watershed.

3.2. Land Cover and Land Use

Land cover and land use are important parameters to consider when determining *E. coli* loads to receiving waterbodies. For example, if most of a watershed was covered by agricultural operations, it would be expected that livestock-derived *E. coli* would make up an important component of the total load. Land cover data for the Blacks Fork Watershed were obtained from the 2006 National Land Cover Data program (Fry et al. 2006). Results indicate that land cover is dominated by forests and rangeland, whereas development and crop production represent the least amount of land cover (Figure 3.2). Land cover in the Blacks Fork Watershed is summarized in Table 3.2 and 3.3. Approximately 67% of the land is covered by shrub/scrub, 12% is evergreen forest, and 8% is grassland. Evergreen forests are most predominant in the headwaters region where shrub/scrub and grassland dominate the lowlands.

The primary land uses in the Blacks Fork Watershed are agricultural and include extensive grazing throughout the scrub/shrub and grassland regions with some hay and small grain production. In areas where lands have been converted to pasture and crops, riparian forests and woody wetlands have been removed by clearcutting, vegetation treatments, or grazing. Much of the impaired reaches in the Blacks Fork Watershed have very limited areas of riparian forests or woody wetlands, particularly in the Lower Smiths Fork subwatershed.

Table 3.2. Predominant Land Cover in the Blacks Fork Watershed (acres)

Subwatershed	Land Cover										
	Shrub/ Scrub	**Grassland/ Herbaceous**	**Pasture/ Hay**	**Cultivated Crops**	**Emergent Herbaceous Wetlands**	**Woody Wetlands**	**Developed**	**Evergreen Forest**	**Deciduous Forest**	**Mixed Forest**	**Barren Land**
Blacks Fork Headwaters	20,441	6,573	389	0	1,126	2,472	654	66,636	4,988	3,650	13,802
Blacks Fork	3,158	2,330	4,950	0	2,530	2,319	378	83	79	12	0
Fort Bridger	25,829	3,363	8,342	0	3,255	1,124	1,356	15	72	18	118
Lyman	13,104	1,207	6,821	32	2,144	944	2,233	25	14	0	88
Smiths Fork Headwaters	9,942	5,433	0	0	1,553	1,442	653	58,242	2,365	1,479	3,807
Upper Smiths Fork	20,404	2,727	15,860	0	3,413	1,101	844	3,970	1,802	540	2
Smiths Fork	35,354	2,244	18,780	0	2,720	618	1,666	1,630	391	59	666
Cottonwood Creek	63,945	3,068	230	0	491	309	552	12,399	2,187	362	169
Lower Smiths Fork	9,324	614	35	0	25	11	127	0	2	0	10
Muddy Creek	481,201	81,254	2,429	0	4,584	1,837	4,855	16,364	12,300	4,660	7,231
Lower Blacks Fork	211,086	2,749	1,727	0	1,192	149	1,558	4	7	0	6,143
Total	893,788	111,562	59,563	32	23,033	12,326	14,371	159,368	24,207	10,780	32,036

Table 3.3. Predominant Land Cover in the Blacks Fork Watershed (percentage acre)

Subwatershed	Land Cover										
	Shrub/ Scrub	**Grassland/ Herbaceous**	**Pasture/ Hay**	**Cultivated Crops**	**Emergent Herbaceous Wetlands**	**Woody Wetlands**	**Developed**	**Evergreen Forest**	**Deciduous Forest**	**Mixed Forest**	**Barren Land**
Blacks Fork Headwaters	17%	5%	0%	0%	1%	2%	1%	55%	4%	3%	11%
Blacks Fork	20%	15%	32%	0%	16%	15%	2%	1%	1%	0%	0%
Fort Bridger	59%	8%	19%	0%	7%	3%	3%	0%	0%	0%	0%
Lyman	49%	5%	26%	0%	8%	4%	8%	0%	0%	0%	0%
Smiths Fork Headwaters	12%	6%	0%	0%	2%	2%	1%	69%	3%	2%	4%
Upper Smiths Fork	40%	5%	31%	0%	7%	2%	2%	8%	4%	1%	0%
Smiths Fork	55%	3%	29%	0%	4%	1%	3%	3%	1%	0%	1%
Cottonwood Creek	76%	4%	0%	0%	1%	0%	1%	15%	3%	0%	0%
Lower Smiths Fork	93%	6%	0%	0%	0%	0%	1%	0%	0%	0%	0%
Muddy Creek	78%	13%	0%	0%	1%	0%	1%	3%	2%	1%	1%
Lower Blacks Fork	94%	1%	1%	0%	1%	0%	1%	0%	0%	0%	3%
Total	67%	8%	4%	0%	2%	1%	1%	12%	2%	1%	2%

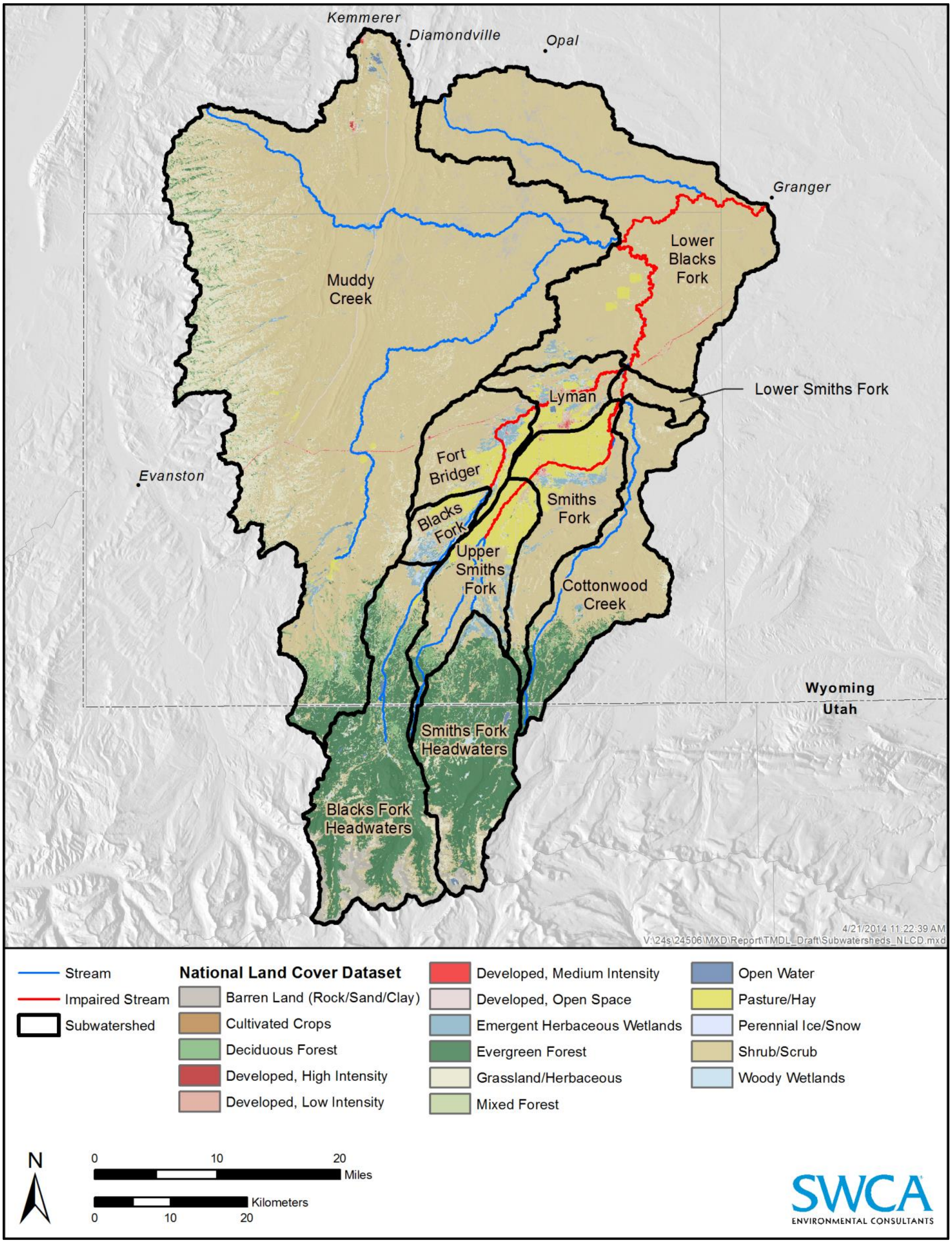

Figure 3.2. Land cover in the Blacks Fork Watershed.

3.3. Geology and Soils

3.3.1. Geology

Many of the surficial geologic features in the Blacks Fork and Smiths Fork subwatersheds were formed during the Eocene epoch (from 56 to 33 million years ago) and include the Bridger, Wasatch, and Green River Formations. The Quaternary (most recent) formations consist of alluvial deposits along streams, lacustrine deposits in the valley, and glacial deposits at higher elevations. The predominant formation is Bridger, which comprises approximately 28% of the Blacks Fork Watershed and consists of large alluvial, colluvial, and landslide deposits, which are all highly erodible (Figure 3.3) (Love and Christiansen 1985). A summary of geologic formations in the Blacks Fork Watershed is shown in Figure 3.4.

3.3.2. Soils and Erodibility

Soils in the Blacks Fork Watershed are primarily loams, which comprise approximately 38% of all classified soils (Figure 3.5). Fine sandy loams make up approximately 21% of remaining soils, with sandy and sandy-clay loams existing throughout 19% of the watershed.

Soil erodibility increases with its representative K factor, a function of soil organic matter, soil structure, particle size, soil permeability to water, and clay content. For example, soils high in clay content have a low K factor (0.05–0.15), whereas soils high in silt content generally have a high K factor (greater than 0.4) and are the most erodible type of soil. Figure 3.6 illustrates the distribution of whole soil K factors throughout the Blacks Fork Watershed. Most soils found in the subwatersheds are loamy (i.e., a combination of sand, silt, and clay) and relatively erodible.

Figure 3.3. A typical landscape along the Smiths Fork River showing the highly erodible Bridger Formation in the background.

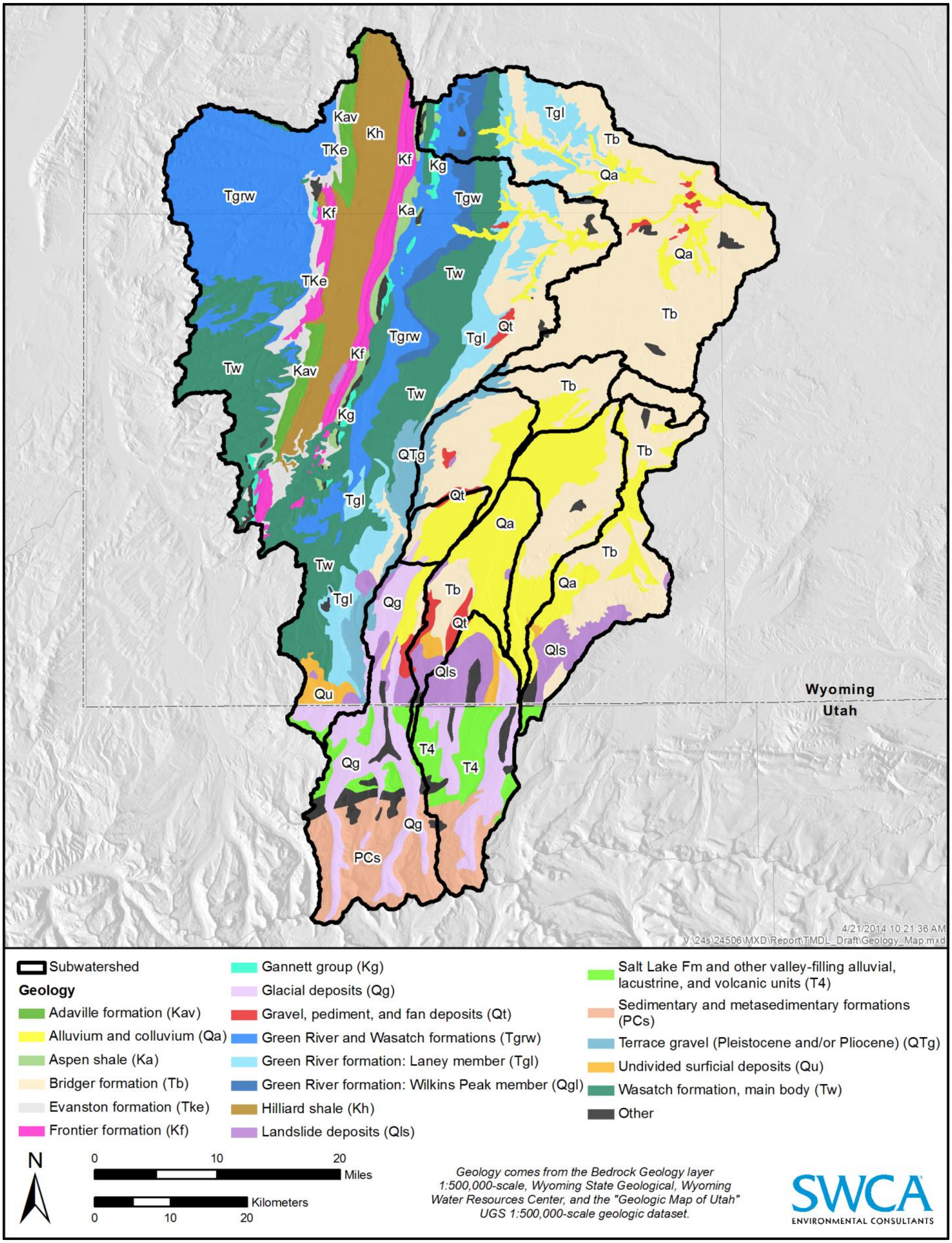

Figure 3.4. Geologic map of the Blacks Fork Watershed.

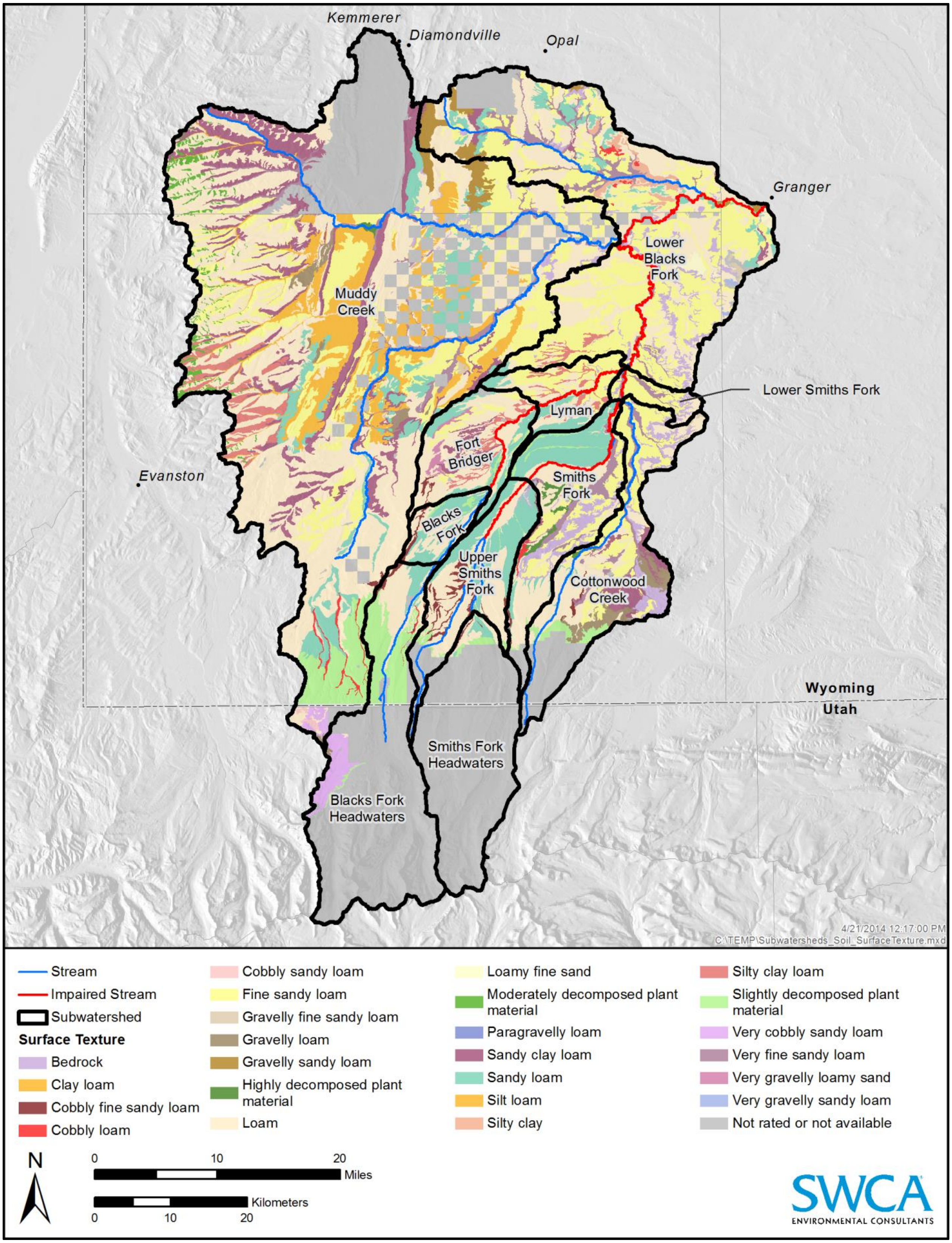

Figure 3.5. Soil texture in the Blacks Fork Watershed.

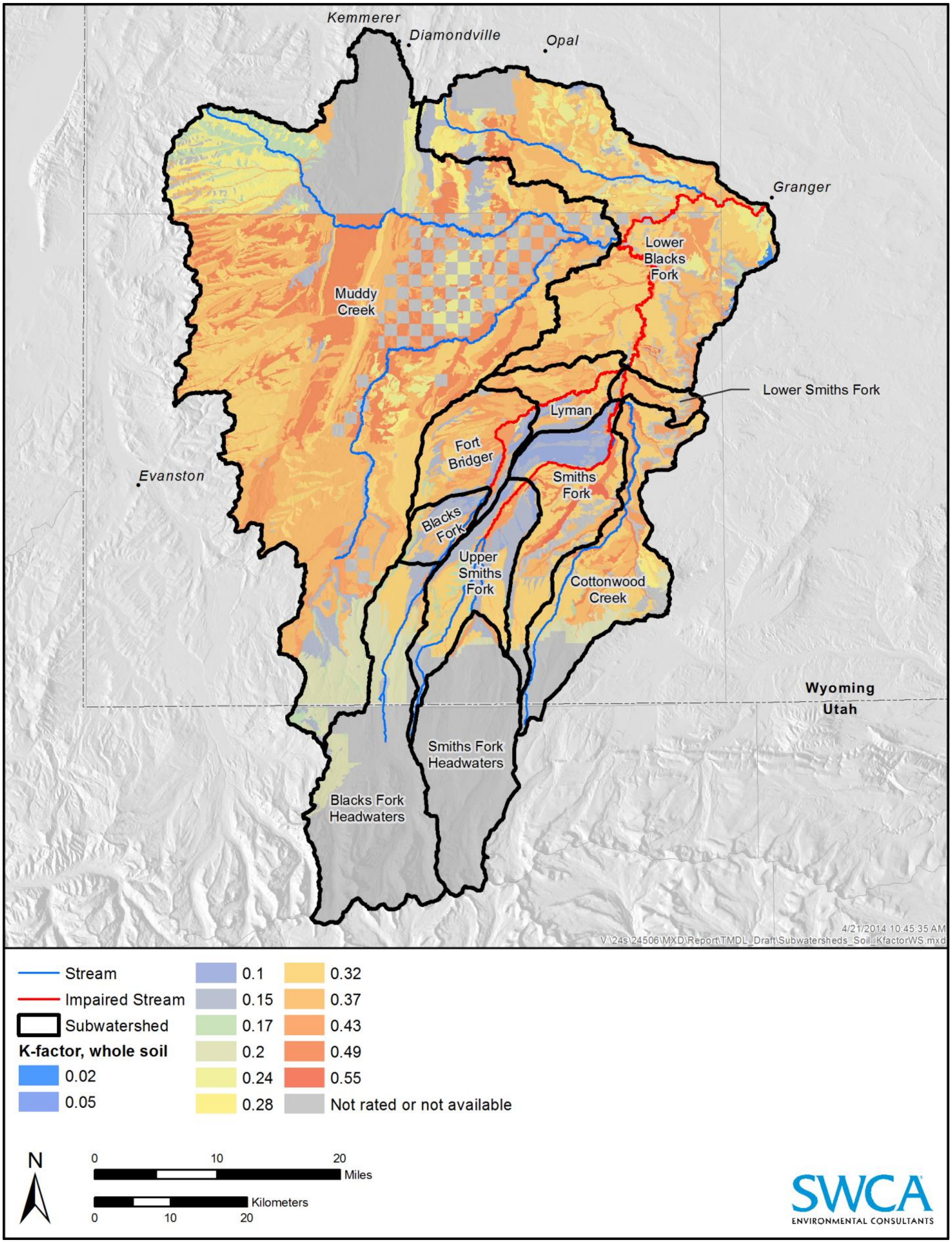

Figure 3.6. Soil erodibility (K-factor) map of the Blacks Fork Watershed.

3.4. Fisheries and Wildlife

The Blacks Fork Watershed is home to various wildlife species and contains several reservoirs and stream reaches that are popular fishing and recreational destinations. Fish species in the region include cutthroat (*Oncorhynchus clarki*), whitefish (*Prosopium williamsoni*), brook trout (*Salvelinus fontinalis*), rainbow trout (*Oncorhynchus mykiss*), and brown trout (*Salmo trutta*). Blacks Fork Headwaters and Smiths Fork Headwaters (west and east fork) have been identified by the Wyoming Game and Fish Department (WGFD) as popular fishing destinations (WGFD 2011).

Big-game species in the Blacks Fork Watershed include mule deer (*Odocoileus hemionus*), elk (*Cervus canadensis)*, moose (*Alces alces*), and antelope (*Antilocapra americana*). Common mammals in the area include yellow-bellied marmot (*Marmota flaviventris*), gopher (*Thomomys* spp.), coyote (*Canis latrans*), porcupine (*Erethizon dorsatum*), striped skunk (*Mephitis mephitis*), and raccoon (*Procyon lotor*). Waterfowl and shorebird species in and near the reservoirs in the area (see section 3.5.1) include mallard (*Anas platyrhynchos*), gadwall (*Anas strepera*), northern pintail (*Anas acuta*), teal (*Anas* spp.), redhead (*Aythya americana*), Canada goose (*Branta Canadensis*), sandhill crane (*Grus canadensis*), killdeer (*Charadrius vociferous*), great blue heron (*Ardea herodias*), Clark's grebe (*Aechmophorus clarkii*), western grebe (*Aechmophorus occidentalis*), gulls (*Larus* spp.), and plovers (*Pluvialis* spp.). It is likely that some of these waterfowl and shorebird species also use riparian habitats along tributary streams.

3.5. Hydrology

3.5.1. Stream Network

The Blacks Fork River and its tributaries are part of the Green River Basin and originate in the Uinta Mountains of northeast Utah and the Tunp and Wyoming Range. A number of tributaries join the Blacks Fork, which flows through Bridger Basin before reaching Flaming Gorge Reservoir. Major tributaries include the Smiths Fork, Cottonwood Creek, Muddy Creek, and Little Muddy Creek (Figures 3.7 and 3.8). Diversions and impoundments exist in the Blacks Fork Watershed and divert water to and from the Blacks Fork and its tributaries. Structures include dams, diversions, and wastewater treatment plants (WWTPs), all of which are discussed in more detail in later sections of this report (section 4.1). The following impoundments in the upper watershed are important sources of irrigation water, and could have a direct effect on stream hydrology and water quality in this area:

- Rollins Reservoir
- Wall Reservoir
- Byrne Reservoir
- Guild and Dean Reservoir
- Guild Reservoir
- Piedmont Reservoir
- Meeks Cabin Dam
- Stateline Dam

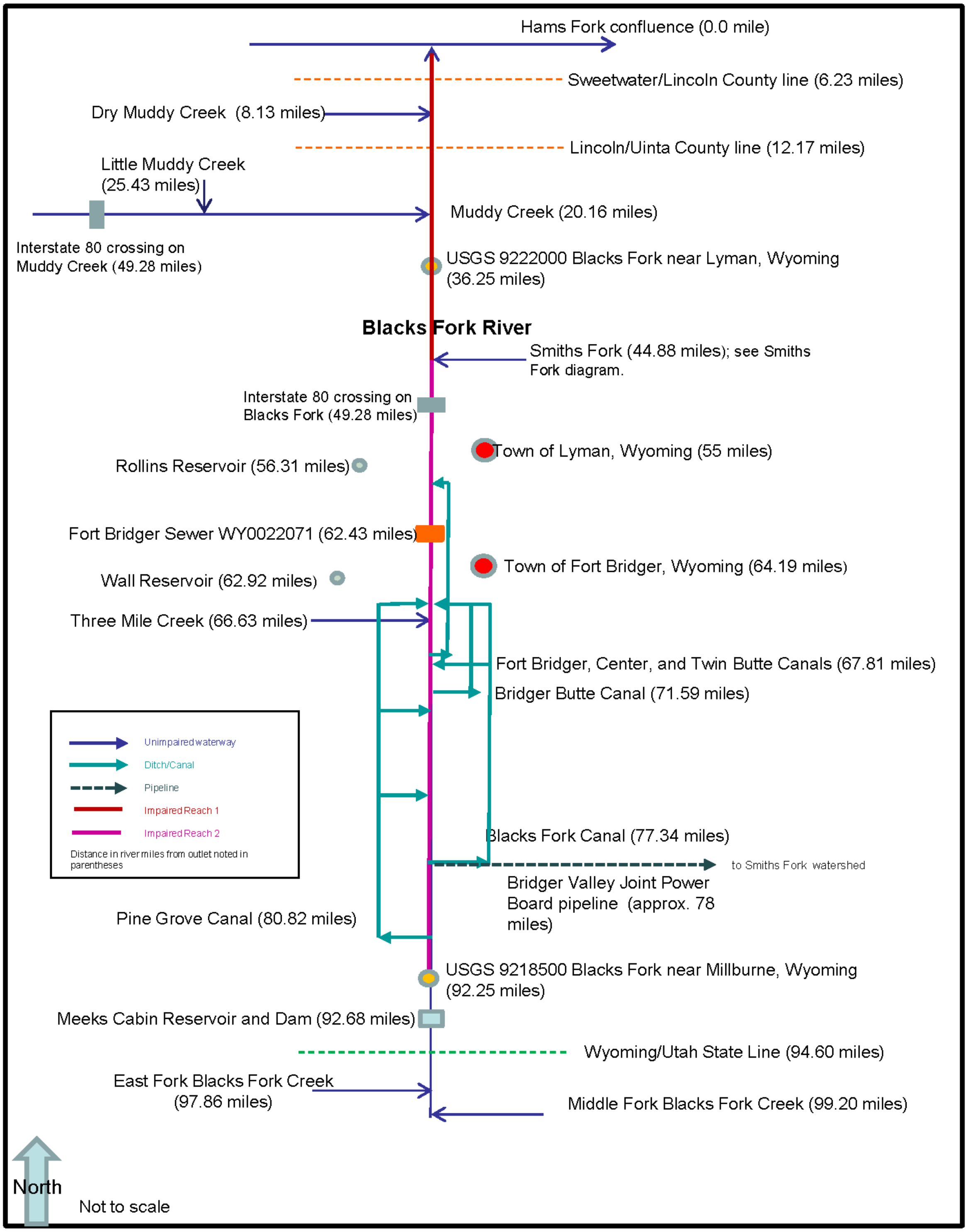

Figure 3.7. Schematic diagram showing the stream network for Blacks Fork River.

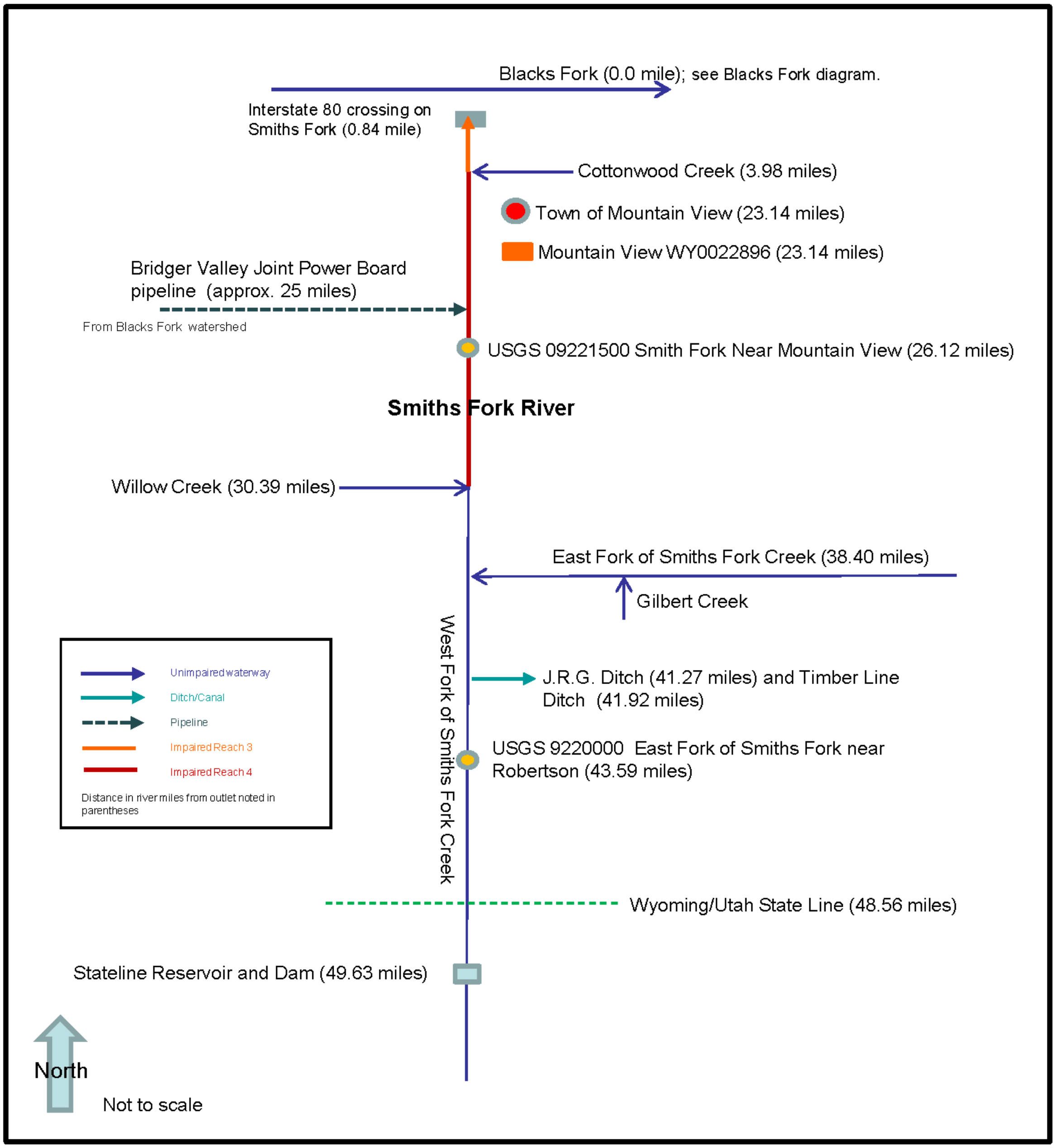

Figure 3.8. Schematic diagram showing the stream network for Smiths Fork River.

3.5.2. Water Diversions

Historical data suggest that 44 diversions in the Blacks Fork Watershed take over 130,000 acre-feet per year from the system (Wyoming Water Development Commission [WWDC] 2009). This estimate includes areas downstream of the Blacks Fork Watershed to Flaming Gorge Reservoir. Many diversions in the Blacks Fork Watershed are along Upper Blacks Fork and Smiths Fork, whereas fewer diversions are present on Dry Muddy Creek and the Middle Blacks Fork. The Bridger Valley Joint Powers Board pipeline is an inter-basin transfer that brings water into Smiths Fork from Blacks Fork (WWDC 2009). Diversion structures that are allowed to divert 10 cubic feet per second (cfs) of water or more are listed in Table 3.4.

Table 3.4. Major Water Diversions in the Blacks Fork Watershed

Diversion Name	Source	Latitude	Longitude	Allocated Water Amount (cfs)
Blacks Fork Canal	Blacks Fork River	41.19517719730	-110.46356171600	93.4
Milich Ditch	East Fork of the Smiths Fork	41.14243135520	-110.39615347000	57.4
Uinta Canal No. 3	Blacks Fork River	41.30602598650	-110.39406305400	57.1
Pine Grove Canal	Blacks Fork River	41.16554790000	-110.49788010000	52.7
Enl. Blacks Fork Canal	Blacks Fork River	41.19584859140	-110.46349304800	28.0
Lamb Supply Canal	Blacks Fork River	41.18588442790	-110.47364055400	26.9
Twin Buttes Canal	Blacks Fork River	41.28742548180	-110.39120177300	23.6
Bridger Butte Canal	Blacks Fork River	41.25470651020	-110.41435770000	23.5
Enl. Pine Grove Canal	Blacks Fork River	41.16531901540	-110.49800217500	22.0
Enl. Deeben-Heinze Ditch	Blacks Fork River	41.33225601900	-110.38532723000	15.9
Enl. Blacks Fork Canal	Blacks Fork River	41.19585241400	-110.46247066900	15.6
Timber Line Ditch	East Fork of the Smiths Fork	41.07388045540	-110.40772024300	14.8
Enl. Blacks Fork Canal	Blacks Fork River	41.19512761870	-110.46198999800	14.7
Fort. Bridger Canal	Blacks Fork River	41.28044072120	-110.39407049100	14.0
Enl. J.R.G. Ditch	East Fork of the Smiths Fork	41.082361	-110.408111	10.9

Note: The list includes water diversions allocated at least 10 cfs.

Source: Wyoming State Engineer's Office (2013).

3.5.3. Reservoir Management and Releases

Built as part of the Lyman Project, Meeks Cabin and Stateline Dams regulate the flow of Blacks Fork and the East Fork of Smiths Fork as they move from the Uinta Mountains through Bridger Valley to the Green River. Meeks Cabin Dam is in Wyoming, 2 miles north of the Utah border. The duly named Stateline Dam is 0.5 mile from the border on the Utah side. Meeks Cabin Reservoir has a total capacity of 32,470 acre-feet and a total release of 29,480 acre-feet per year. Stateline Reservoir is considerably smaller, with a total capacity of 14,000 acre-feet and total release of 12,000 acre-feet per year (U.S. Bureau of Reclamation [BOR] 2009). Figures 3.9 and 3.10 show the storage-elevation curve for Meeks Cabin Reservoir and Stateline Reservoir.

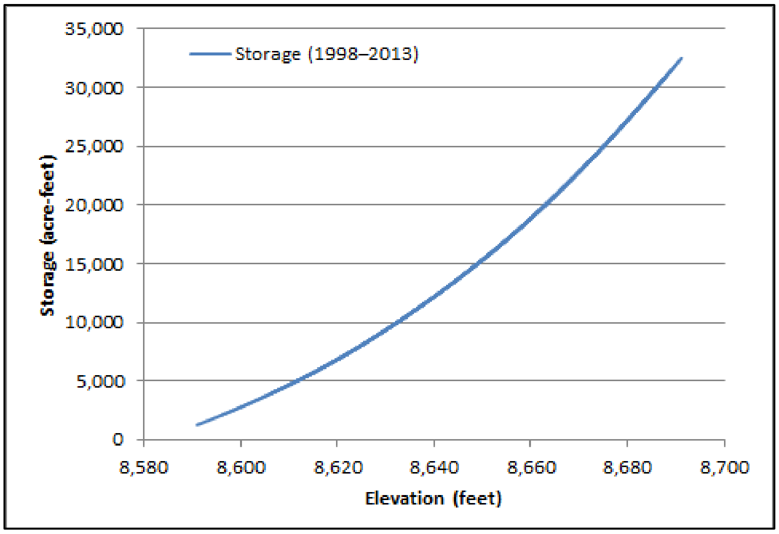

Figure 3.9. Storage-elevation curve for Meeks Cabin Reservoir.

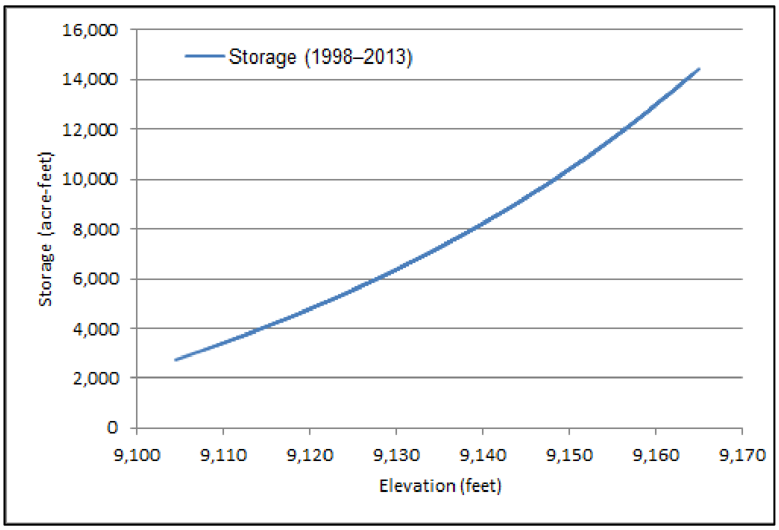

Figure 3.10. Storage-elevation curve for Stateline Reservoir.

Both Meeks Cabin and Stateline Reservoirs begin to fill in October. A moderate amount of storage is accumulated during the fall, whereas most is accumulated during the spring snowmelt, reaching a storage peak in June. Water is then released in the summer months, resulting in an annual low elevation and storage in October. The annual elevation fluctuation is shown in Figure 3.11 for Meeks Cabin and Stateline Reservoirs.

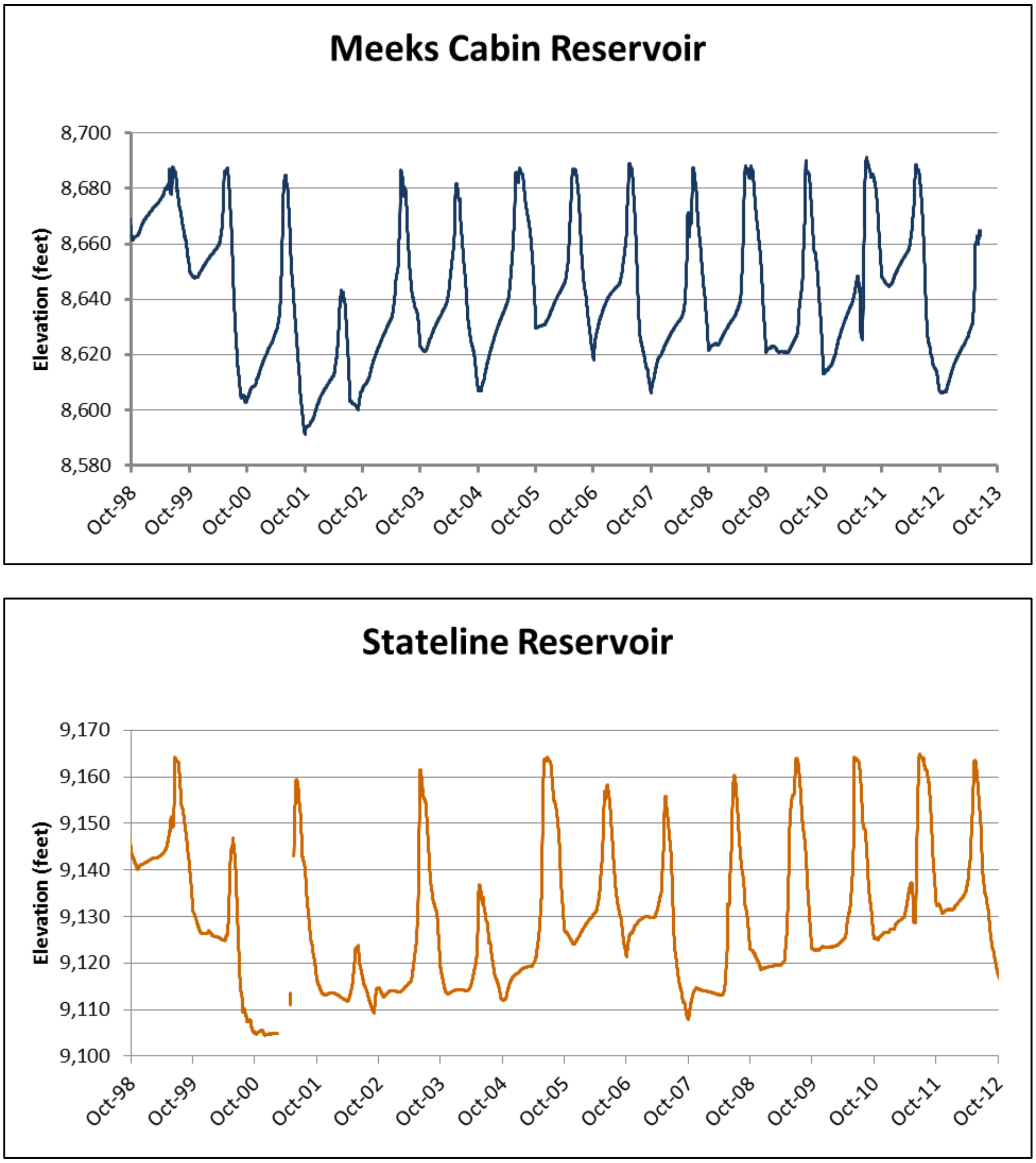

Figure 3.11. Reservoir pool elevation for Meeks Cabin and Stateline Reservoirs for water years 1998–2012.

Although not discussed in detail in this report, other reservoirs exist in the Blacks Fork Watershed. Moslander Reservoir is at the south tip of the Muddy Creek subwatershed. Four small reservoirs (Burne, Guild, Piedmont, and Guild and Dean Reservoirs) sit to the north near the headwaters of Muddy Creek. Wall and Rollins Reservoirs are near Lyman, Wyoming, at the north end of the Upper Blacks Fork subwatershed. Just north of these is Austin Reservoir, which is in the Blacks Fork subwatershed. East of Mountain View is the Clifford F Graham Reservoir in the Smiths Fork subwatershed. Because data were insufficient for these above-listed reservoirs, Meeks Cabin and Stateline Reservoirs are the primary focus for this study.

3.5.4. Existing Data Description

3.5.4.1. BLACKS FORK BASIN MODEL FLOWS

The Wyoming State Engineer's Office (SEO) has developed a hydrologic model for the Green River, which includes a model for the Blacks Fork Basin. The Blacks Fork Basin model includes the Blacks Fork River to Flaming Gorge Reservoir, the Smiths Fork River, and the Hams Fork River (SEO 2011), thereby including the pathogen-impaired reaches on Blacks Fork and Smiths Fork and the habitat-impaired reach on Smiths Fork (Figure 3.12). The Blacks Fork Basin model estimates monthly flow volumes that account for irrigation diversions and returns within the watershed for normal, wet, or dry hydrologic conditions at multiple nodes in the watershed. Nodes indicate a specific point, such as a USGS gage or a stream reach, for which the net flow is calculated (based on flow in, net diversions, and flow out) and provide an estimate of flow at multiple locations in the watershed (Figure 3.13). The Blacks Fork Basin model incorporated data from 1971 to 2007, and each of these years was classified into one of the three hydrologic conditions based on percentiles. The wettest 20% of years was considered wet, whereas the driest 20% was classified as dry. The remaining years were classified as normal (AECOM 2008). Years not yet included in the Blacks Fork Basin model were assigned a hydrologic condition using the same percentiles (see section 3.5.4.2). A separate flow database was developed to organize and compile the monthly net flows from each node under each hydrologic condition from the Blacks Fork Basin model.

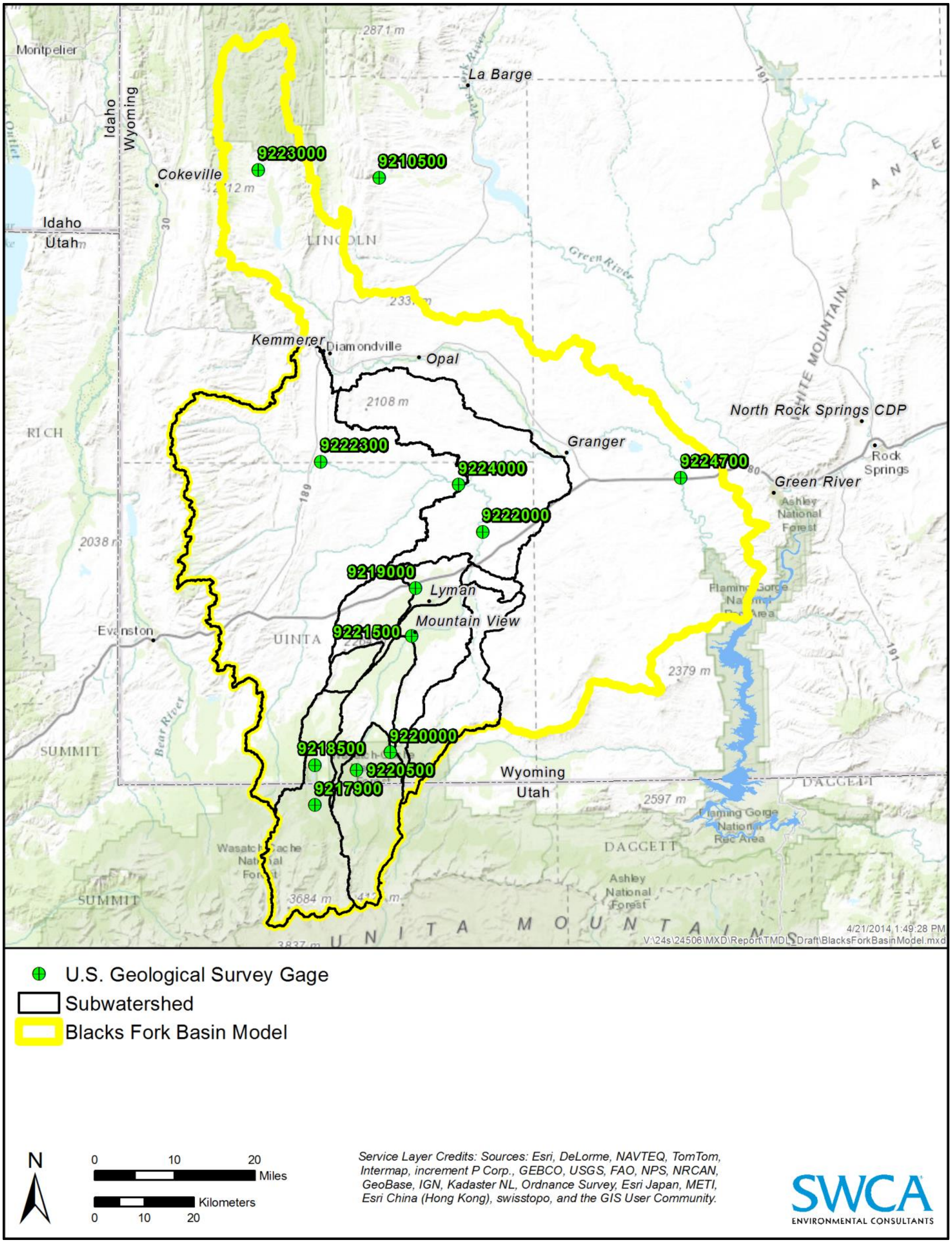

Figure 3.12. The Blacks Fork Basin model boundaries encompass the Blacks Fork Watershed and therefore include the impaired reaches.

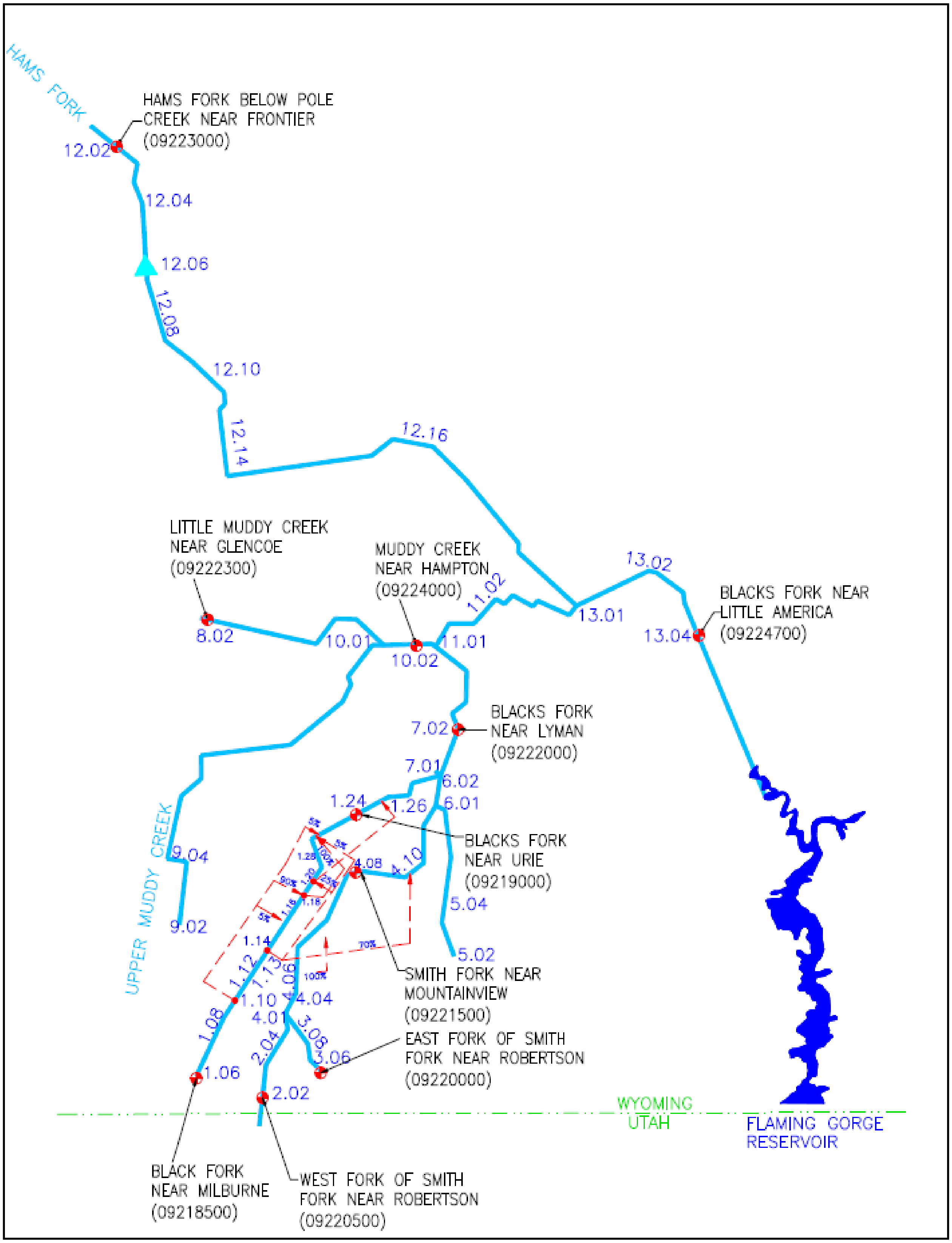

Figure 3.13. The Blacks Fork Basin model nodes (SEO 2011). Blue numbers indicate location and identification of model nodes; red symbols indicate location of USGS stream gages.

3.5.4.2. U.S. GEOLOGICAL SURVEY FLOW DATA

In addition to model estimates, real flow data are available for the Blacks Fork Watershed from the USGS and UCCD, both of whom monitor flow in the Blacks Fork Watershed. The USGS maintains gages that record continuous flow data, whereas the UCCD takes discharge measurements at water quality monitoring sites during routine sample collection. USGS data were used in conjunction with BOR data from Meeks Cabin Dam to assign a hydrologic condition to the years 2008–2012, which were not yet incorporated into the model. The USGS data were also used to assess the general flow regime for the watershed and to define periods of spring runoff and late summer low flow.

The USGS gage at Millburne was not operational between September 1998 and April 2013; therefore, flows were estimated for this time period using a linear regression. The regression was developed using the Meeks Cabin Dam outflow data to predict flow at the USGS gage because Meeks Cabin Dam is physically close to the USGS gage. Seasonal flow patterns also match well, indicating little additional influence from other sources of flow. The regression equation has an R-squared value of 0.95, indicating a strong relationship between Meeks Cabin Dam outflows and flow at the USGS gage (Figure 3.14). The regression equation was used to estimate daily flow at the USGS gage for the time period between 1998 and 2012.

The Blacks Fork Basin model uses flow data from the USGS at Millburne to determine the hydrologic condition of each year for Blacks Fork, Smiths Fork, and their tributaries. The estimated flow volume for each year is assigned a hydrologic condition based on percentiles. If the flow volume for a given year is within the upper 20% of flow volumes between 1971 and 2007, the year is classified as wet. The years with flow volumes in the lower 20% are classified as dry. Remaining years are classified as normal. The years 2008–2012 were assigned a hydrologic condition using the percentiles already calculated for the model using the 1971–2007 data set (Table 3.5). This approach is appropriate because it matched a hydrologic condition already set in the model, not updating the model with additional data. Notably, 2011 is the only wet year between 2008 and 2012. That year was also one of the wettest on record; the flow volume for 2011 exceeds the upper limit of flows classified as wet.

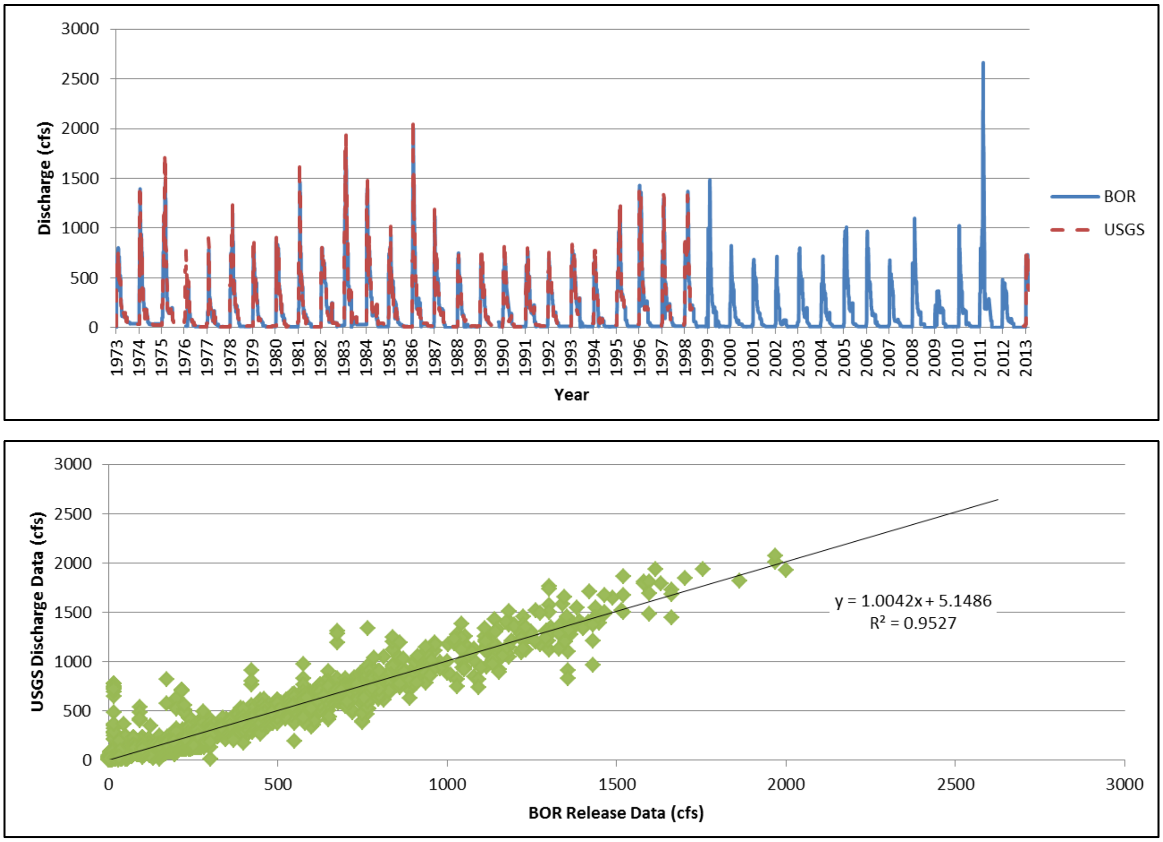

Figure 3.14. The regression analysis (below) and hydrograph (above) using outflows from Meeks Cabin Dam. These can be used to estimate flow at the U.S. Geological Survey gage at Millburne (09218500).

Table 3.5. Hydrologic Conditions for Years not yet Included in the Blacks Fork Basin Model Based on Estimated Flow at the U.S. Geological Survey Gage near Millburne

Year	Estimated Flow Volume (thousand acre-feet)	Blacks Fork Basin Model Hydrologic Condition
2008	120.41	Normal
2009	67.16	Dry
2010	95.28	Normal
2011	206.44	Wet
2012	71.34	Dry

The hydrograph at the USGS gage 09224700 (Blacks Fork at Little America) was used to describe flow near the outlet of the Blacks Fork Watershed. This gage is currently active, whereas the USGS gage at Lyman (09222000) is no longer active. The estimated flows for the USGS gage at Millburne are highly influenced by releases from Meeks Cabin Dam. Even with reservoir and irrigation activities, these hydrographs show the typical snowmelt-dominated hydrology expected in southwestern Wyoming, with peak flows generally occurring around June during a normal year. Spring runoff may begin as early as mid-March, whereas low flows occur in August and endure through the winter. The years 2010–2012 were selected as representative normal, wet, and dry years for purposes of developing hydrographs shown in Figures 3.15 and 3.16.

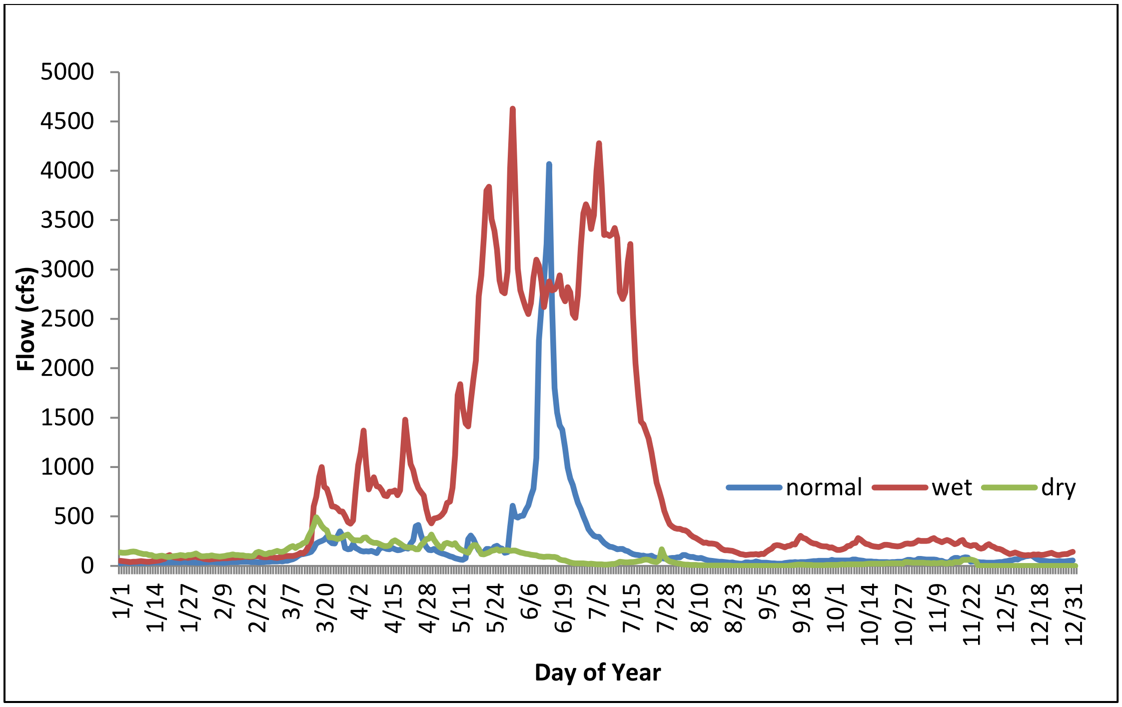

Figure 3.15. Representative wet (2011), dry (2012), and normal (2010) years. Flows at U.S. Geological Survey gage Blacks Fork at Little America (09224700).

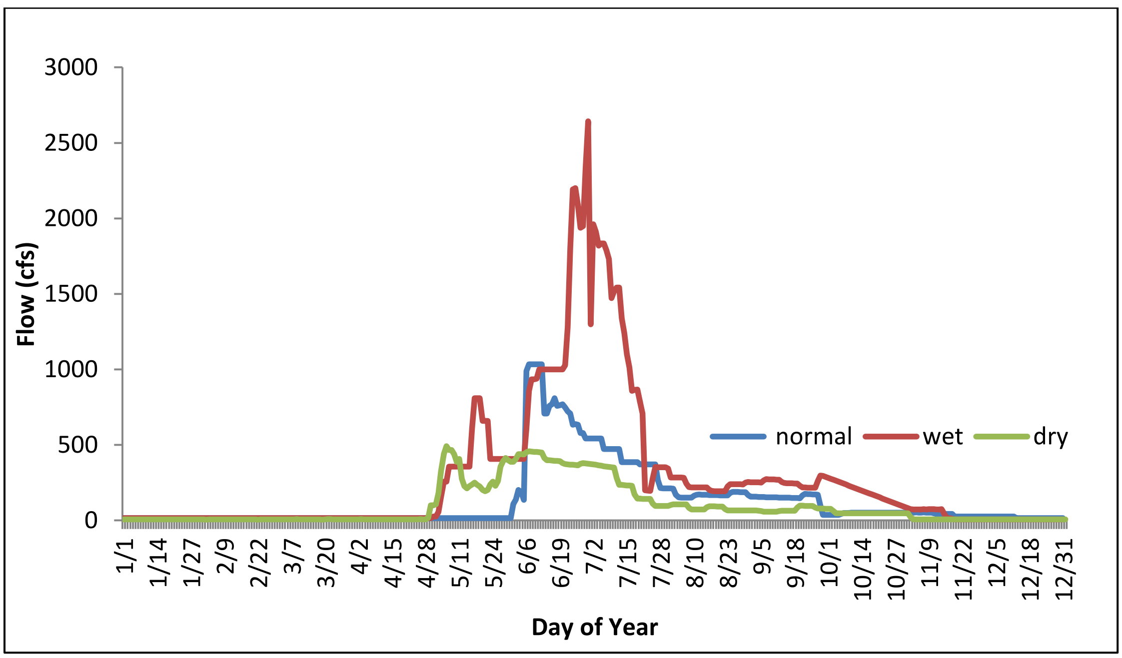

Figure 3.16. Representative wet (2011), dry (2012), and normal (2010) years. Flows were estimated for U.S. Geological Survey gage 09218500 using Bureau of Reclamation outflow data from Meeks Cabin Dam.

3.5.4.3. SUPPLEMENTAL FLOW DATA

In addition to the USGS-maintained gages in the Blacks Fork Watershed, other entities collect flow data along the streams. The UCCD conducts streamflow measurements as part of their water quality monitoring program. Additionally, the SEO maintains an interactive website that allows users to download flow data at diversions as well as tributaries within the watershed (SEO 2013). The STORET data set contains streamflow measurements taken in conjunction with water quality sampling that both the WDEQ and the Utah Department of Environmental Quality (UDEQ) have completed. Supplemental flow data were used in the habitat alteration analysis to construct a sediment rating curve for the Lower Smiths Fork. Other supplemental flow data were not used in the analyses.

3.6. Water Quality

3.6.1. Existing Data Description

Water quality data were obtained from the WDEQ, UCCD, and UDEQ. The WDEQ and UCCD provided water quality data collected from multiple sites within the watershed below Stateline Dam on Smiths Fork and below Meeks Cabin Dam on Blacks Fork. The UCCD has been actively monitoring water quality, including *E. coli*, at several sites on the Blacks Fork and Smiths Fork since 2002 as part of the *Blacks Fork/Smiths Fork Watershed Report* (WWC Engineering 2006). STORET was queried to obtain UDEQ data from the upper watershed (Figure 3.17). These data were compiled into a database used for multiple analyses to support development of the TMDL. Most data were received in electronic format as Excel spreadsheets. However, UCCD data collected before 2007 were obtained in paper format from an appendix in a watershed report completed in 2006 (WWC Engineering 2006). Data from 2002 to present, including UCCD data collected through May 2013, were included in the water quality analysis. All relevant pathogen data are presented in Table 3.6.

All data sets were combined into a single database and assigned additional characteristics useful in the TMDL analysis and load calculations, including hydrologic condition and irrigation season (see section 3.7.2). Although the original values, units, and characteristic names were kept as attributes, the database assigned each entry a standardized name with standard units for each characteristic to simplify queries and analytical procedures. A list of database characteristics and their descriptions are included in Table 3.7. Nondetects and values greater than quantitation were also converted to numeric values (see section 3.6.3).

Table 3.6. Number of Pathogen Observations at Monitoring Sites in the Blacks Fork Watershed from 1998 to 2012

Reach	Site/Gage Number	*E. coli* Geomean	Years Calculated	*E. coli* Samples	Years Sampled	Fecal Coliform Samples	Years Sampled	Total Coliform Geomean	Years Calculated	Total Coliform Samples	Years Sampled
Blacks Fork Reach 2	09222000 (USGS)	–	–	30	2001–2008	39	1998–2007	–	–	–	–
	WB0236 (WDEQ)	–	–	0	–	5	2000	–	–	–	–
Reach 2total	–	*0*	*0*	*30*	–	*43*	–	*0*	–	*0*	–
Blacks Fork Reach 1	BF3 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
	BF4 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
	BF5 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
	BF7 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
	BF8 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
	TM1 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
Reach 1 total	–	*72*	–	*360*	–	*0*	–	*24*	–	*360*	–
Smiths Fork Reach 3	SF1 (UCCD)	12	2007–2010	59	2007–2010	–	–	4	2007–2008	59	2007–2012
	WB30 (WDEQ)	–	–	–	–	7	2000–2001	–	–	–	–
Reach 3 total	–	*12*	–	*59*	–	*7*	–	*4*	–	*59*	–
Smiths Fork Reach 4	SF2 (UCCD)	12	2007–2010	57	2007–2012	–	–	4	2007–2008	57	2007–2012
	SF3 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
	SF4 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
Reach 4 total		*36*		*177*		*0*		*12*		*177*	
Blacks Fork unimpaired reaches	BF10 (UCCD)	11	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012
Blacks Fork unimpaired reaches total	–	*11*	–	*60*	–	*0*	–	*4*	–	*60*	–
Smiths Fork unimpaired reaches	SF10 (UCCD)	–	–	36	2007–2012	–	–	–	–	36	2007–2012
	SF5 (UCCD)	12	2007–2010	60	2007–2012	–	–	4	2007–2008	60	2007–2012

Table 3.6. Number of Pathogen Observations at Monitoring Sites in the Blacks Fork Watershed from 1998 to 2012

Reach	Site/Gage Number	*E. coli* Geomean	Years Calculated	*E. coli* Samples	Years Sampled	Fecal Coliform Samples	Years Sampled	Total Coliform Geomean	Years Calculated	Total Coliform Samples	Years Sampled
Smiths Fork unimpaired reaches total		*12*	*–*	*96*	*–*	*0*	*–*	*4*	*–*	*96*	*–*
Unknown reach	DE1 (UCCD)	–	–	9	2011	–	–	–	–	9	2011
	KS1 (UCCD)	–	–	27	2011–2012	–	–	–	–	27	2011–2012

Notes: Reach 1 = Blacks Fork from Smiths Fork upstream to Millburne (fecal coliform impairment [converted to *E. coli*]); Reach 2 = Blacks Fork from Hams Fork upstream to Smiths Fork (*E. coli* impairment); Reach 3 = Smiths Fork from Blacks Fork upstream to Cottonwood Creek (*E. coli* impairment); Reach 4 = Smiths Fork from Cottonwood Creek upstream to the East Fork and West Fork of Smiths Fork (fecal coliform impairment [converted to *E. coli*]).

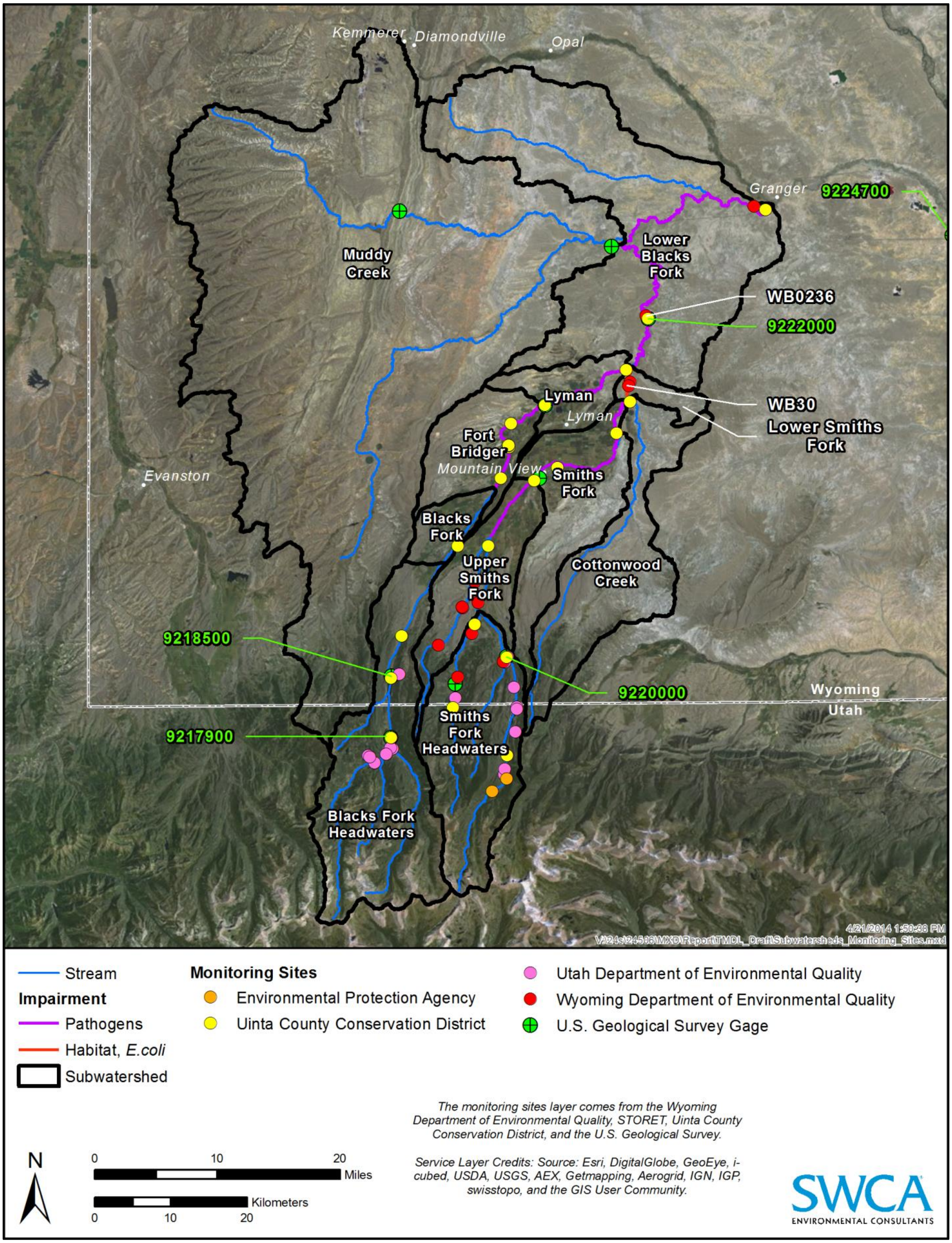

Figure 3.17. Water quality and flow monitoring sites by agency in the Blacks Fork Watershed.

Table 3.7. A List of Attributes included in the Water Quality Database for Blacks Fork Watershed Total Maximum Daily Loads

Attribute	Description
Agency	Identifies the agency that collected the data.
Station Code	The station identification number or code assigned to a sampling site.
Station Name	The name/description of the sampling site. The UCCD did not have descriptive names for their sites, so SWCA Environmental Consultants created names for use in this project.
Collection Date	The month, day, and year that the sample was collected.
Month	The month the sample was collected.
Day	The day of the month the sample was collected.
Year	The year the sample was collected.
Time	The time, if available, that the sample was collected.
Duplicate or blank	Identifies duplicate or blank QA/QC samples using a value of 1. If the entry is not a duplicate or blank, the value is 0.
Exclude	A value of 1 indicates that the entry should be excluded, likely because it is a duplicate or blank result.
Characteristic name_original	The characteristic name in the raw data set that the entry came with.
Characteristic name_standardized	The standard name used in the database for a characteristic to simplify analyses.
Sample Fraction	Includes any useful descriptor for the data, including dissolved, total, filtered, as N, as P, etc.
ChemValue_original	The value in the original data.
ChemUnits_original	The units for the original data
ChemNumericValues_inoriginalunits	Water quality values in original units
Chem_NumericValues_standardized units	The original value converted to standard units for a characteristic; for example, all flow measurements are converted to cfs.
Standardized units	Units used for each standardized characteristic
Below detection	A 1 indicates if the result is below detection
Above limit	A 1 indicates if the result is higher than the quantitation limit
Parameter set	This column indicates if the data value is a statistic, a calculated value, part of field data collection, or part of laboratory results.
Latitude	The approximate latitude of the station.
Longitude	The approximate longitude of the season.
County name	The county where the sampling site is located.
Stream	The name of the stream where the sampling site is located.
In impaired reach	Identifies the impaired reach that the sampling site is in, if any.
Analytical Procedure ID	Analytical procedure, which is included with STORET data.
Season	Irrigation season; spring irrigation, summer, and fall irrigation.
Model flow condition	The hydrologic condition associated with each year, based on the Blacks Fork Basin model. See section 3.5.4.1.
Model node	The Blacks Fork Basin model node used for calculating loads into and out of subwatersheds
With habitat data	Indicates if habitat data have been collected at the monitoring site.
With benthic data	Indicates if benthic macroinvertebrate data have been collected at the monitoring site.
Subwatershed	Identifies the subwatershed where the monitoring site is located.

3.6.2. Pairing Water Quality Data with Hydrologic Conditions

Each entry in the water quality database was assigned a model hydrologic condition (normal, wet, or dry) by matching the year the water quality data were obtained and the hydrologic condition associated with each year from the Blacks Fork Basin model. The water quality data were also assigned an irrigation season based on the month the data were collected. The hydrologic and irrigation seasons are outlined in Table 3.9 in section 3.7.2.

Once the hydrologic condition and irrigation season were assigned, the water quality data could be queried by wet, dry, or normal hydrologic conditions. This differentiation is important because it allows for more accurate and representative loading estimates under differing hydrologic conditions. Instead of using all data for each hydrologic condition and only modifying flows, the *E. coli* data and geomeans from a normal year were used to calculate loads for a normal flow year, and water quality data from a dry year can be separated from the larger data set and used to describe water quality conditions under dry hydrologic conditions. Further stratifying the water quality data using irrigation seasons allows for more accurate load estimates over the impairment season and may indicate when high loads occur, which could indicate potential sources of pollutants.

3.6.3. Nondetects and Values above Quantitation

Nondetects are results that analytical laboratories report as below detection or below reporting limits. These data are often indicated with a less than symbol (<) or “nondetect” in place of a value. A common approach to addressing nondetects is to use half the detection limit. This method was used to assign a numeric value to data entries that were entered with a < sign or as “nondetect,” thereby indicating the detection limit. If the detection limit was not known, the entry remained listed as a nondetect. Nondetects are not an issue for water quality constituents such as *E. coli* and total coliform where zero is a real result.

Values above quantitation, which are values higher than some threshold, are indicated with a greater than sign (>) in the water quality database. Seven bacteria data entries were above quantitation. These results were transformed to numeric estimates by multiplying the quantitation limit by 1.5.

3.6.4. Using Fecal Coliform Data to Estimate E. coli

Some older bacteria data contain results for fecal coliform and total coliform instead of *E. coli*. USGS site 09222000 (Blacks Fork near Lyman) contains fecal coliform data collected on a seasonal basis (four times per year) between 1998 and 2000. These fecal coliform data were converted to estimates of *E. coli* because the current state standards use *E. coli* as the indicator bacteria.

Pairs of fecal and *E. coli* data were used to develop a linear regression to estimate *E. coli* concentrations from a fecal coliform concentration. The EPA (2001) recommends this method, which has been used in other bacteria TMDLs. The Goose Creek watershed TMDL (SWCA Environmental Consultants [SWCA] 2010) and Shoshone watershed TMDL (WDEQ 2013d) are two recent examples. The USGS used similar methods to show a relationship between fecal coliform and *E. coli* in several Wyoming streams (Clark and Gamper 2000).

Nineteen pairs of fecal and *E. coli* data points from sampling occurring between 2001 and 2007 were used to generate a linear regression for the Blacks Fork Watershed. Pairs showing *E. coli* greater than fecal coliform were excluded from the analysis because *E. coli* is a portion of fecal coliform and therefore should always be a smaller number. The regression was set to run through the origin as recommended by EPA (2001). The regression equation shows that *E. coli* is 73% of the fecal coliform, with the trend line falling below the 1:1 line (Figure 3.18). This equation is specific to the Blacks Fork Watershed and can be used to estimate *E. coli* from the fecal coliform data gathered from the Blacks Fork if there are no *E. coli* data.

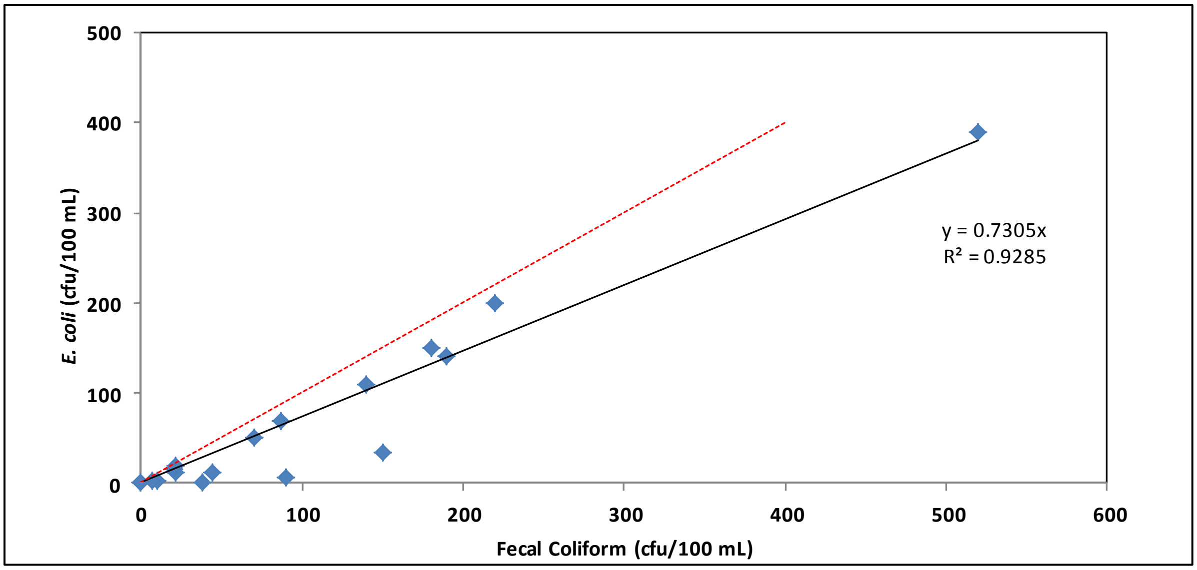

Figure 3.18. Linear regression showing *E. coli* estimated from fecal coliform data. The red line shows a 1:1 ratio, whereas the *E. coli* is shown as 73% of fecal coliform measurements. (*Note*: mL = milliliters; cfu = colony forming unit).

3.6.5. Supplemental Monitoring

Additional samples were taken for *E. coli* analysis to supplement sites where little data were available and also to gain a better understanding of concentrations in the irrigation canals. Samples were taken following the WDEQ coliform bacteria sampling protocol (2011) on three separate dates in fall 2013 (September 3, September 5, and September 25; Table 3.8).

Table 3.8. *E. coli* Concentrations (most probable number/100 mL) for Sites in the Blacks Fork Watershed

Sampling Site	September 3, 2013	September 5, 2013	September 25, 2013
BF1	1.0	3.1	24.6
BF2	10.9	35.0	42.6
Irrigation Canal 1	866.4	1,203.0	431.1
Irrigation Canal 2	1,203.0	1,986.0	361.3
Muddy Creek	Not sampled due to dry conditions	Not sampled due to dry conditions	2.2

3.7. Seasonality

3.7.1. WDEQ Impairment Seasons

The Wyoming state standards for *E. coli* impairment relate to primary and secondary contact use. The primary contact standard for *E. coli* is a geomean of < 126 colony forming units (cfu)/100 milliliters (mL) between May 1 and September 30. The standard for secondary contact is < 630 cfu/100 mL and extends from October 1 to April 30 (WDEQ 2013c). The impairment season of May 1–September 30 is used for the analysis and is further split into loading seasons based on irrigation timing. The impairments in the

Blacks Fork Watershed occur during the summer season due to violations of the water quality standard for primary contact use. Thus, the summer season represents the critical season for the TMDL. A winter TMDL was also calculated using modeled flows and the secondary contact recreation standard (section 5.2.2). In this case, the necessary reductions would be 0% throughout the watershed because *E. coli* data do not indicate any violations of the secondary contact use water quality standard.

3.7.2. Hydrologic Regimes for TMDL Development

The hydrologic regimes used in developing TMDLs for *E. coli* are based on the Blacks Fork Basin model and irrigation operations in the watershed. The Blacks Fork Basin model provides estimates of monthly flow at various locations in the watershed for normal, wet, and dry hydrologic conditions. The impairment season, defined as May 1–September 30 (WDEQ 2013c), was separated into three irrigation seasons based on local irrigation practices. According to the UCCD, irrigation occurs early in the spring from May through June. Little to no irrigation occurs when hay is being cut, generally July through August. A second irrigation may occur in September and October if water is available.[1] As such, May and June are considered the spring loading season, whereas July and August are considered the summer loading season because this timeframe reflects summer thunderstorms and low flow with little influence from irrigation. The fall loading season (September) accounts for loading generated from storm events and any additional irrigation late in the growing season, but it is based on *E. coli* data collected in September and October because there were not enough data in September to characterize this condition.

Hereafter, a *hydrologic regime* refers to a combination of hydrologic condition (normal, wet, or dry) and irrigation season (spring, summer, or fall). Examples of hydrologic regimes are wet-spring, normal-summer, and dry-fall (Table 3.9). These hydrologic regimes are used to group representative *E. coli* data for calculating geomeans that have a similar temporal scale. The hydrologic regimes were assigned to the water quality data entries in the same way that the hydrologic condition was attributed to the water quality data.

Table 3.9. Hydrologic Regimes Created by Combining Hydrologic Condition and Irrigation Season that are used in the Total Maximum Daily Load Analysis

Hydrologic Condition*	Month	Irrigation Season	Hydrologic Regime
Normal	May–June	Spring	Normal-Spring
	July–August	Summer	Normal-Summer
	September	Fall	Normal-Fall
Wet	May–June	Spring	Wet-Spring
	July–August	Summer	Wet-Summer
	September	Fall	Wet-Fall
Dry	May–June	Spring	Dry-Spring
	July–August	Summer	Dry-Summer
	September	Fall	Dry-Fall

* This column includes the three hydrologic conditions from the Blacks Fork Basin model: normal, wet, and dry.

[1] Personal communication, Technical Advisory Committee conference call between Erica Gaddis, SWCA, and Kerri Sabey, UCCD, regarding irrigation practices, August 29, 2013.

4. SOURCE IDENTIFICATION ANALYSIS

This section provides a summary of and rationale for all significant *E. coli* sources that contribute to impairments in the Blacks Fork Watershed. Contributing point sources consist of three WWTPs in the towns of Lyman, Mountain View, and Fort Bridger and a truck stop off Interstate 80 near the town of Fort Bridger that consists of a contained wetland. Nonpoint sources of *E. coli* include agricultural activities, septic systems, pet waste, and wildlife. Agricultural activities consist of grazing on both public and private land as well as flood irrigation practices. Loads entering the subwatersheds from upstream are also of interest because they can contribute significantly to the total load, particularly in the Lower Smiths Fork and Lyman subwatersheds. Contributions from nonpoint sources vary annually and spatially within the watershed, making them difficult to monitor. Furthermore, nonpoint sources are not regulated and would benefit from public outreach to promote the use of voluntary BMPs to mitigate impact.

All of the *E. coli* loads discussed in this section are seasonal and represent the primary contact season for *E. coli* impairment (May 1–September 30). *E. coli* loads are expressed as G-cfu/season or giga (10^9) colony forming units per impairment season (May–September). During the TMDL analysis, no *E. coli* exceedances were found during the winter season (October–April), therefore sources were not examined for this period. Loads are further differentiated and presented based on irrigation timing characterized by a spring (May–June), summer (July–August), and fall (September) season. Within each season, loads are presented during a normal, wet, and dry hydrologic condition based on flows from the Blacks Fork basin model produced by the SEO. All subwatershed loads are presented by hydrologic regime, which is the combination of irrigation season and hydrologic condition (see section 3.7.2). The temporal nature of the hydrologic regime reflects the timeframe for which the TMDL was developed in congruence with the State of Wyoming *E. coli* standard that states that the geomean of five samples collected during a 60-day period cannot exceed 126 organisms per 100 mL.

4.1. Point Sources

Point sources of bacteria affect year-round water quality in the Blacks Fork Watershed at a relatively low and constant rate. During periods of low flow, point sources tend to represent a larger portion of the total load to streams. Four regulated point sources in the watershed discharge bacteria under individual Wyoming Pollutant Discharge Elimination System (WYPDES) permits (Figure 4.1) (WDEQ WYPDES). Point source outfalls were identified through WYPDES permits and are in the Fort Bridger, Lyman, and Smiths Fork subwatersheds. All data were obtained from discharge monitoring reports, which are used as regulatory tools by the WYPDES program to monitor discharge and ensure permit compliance.

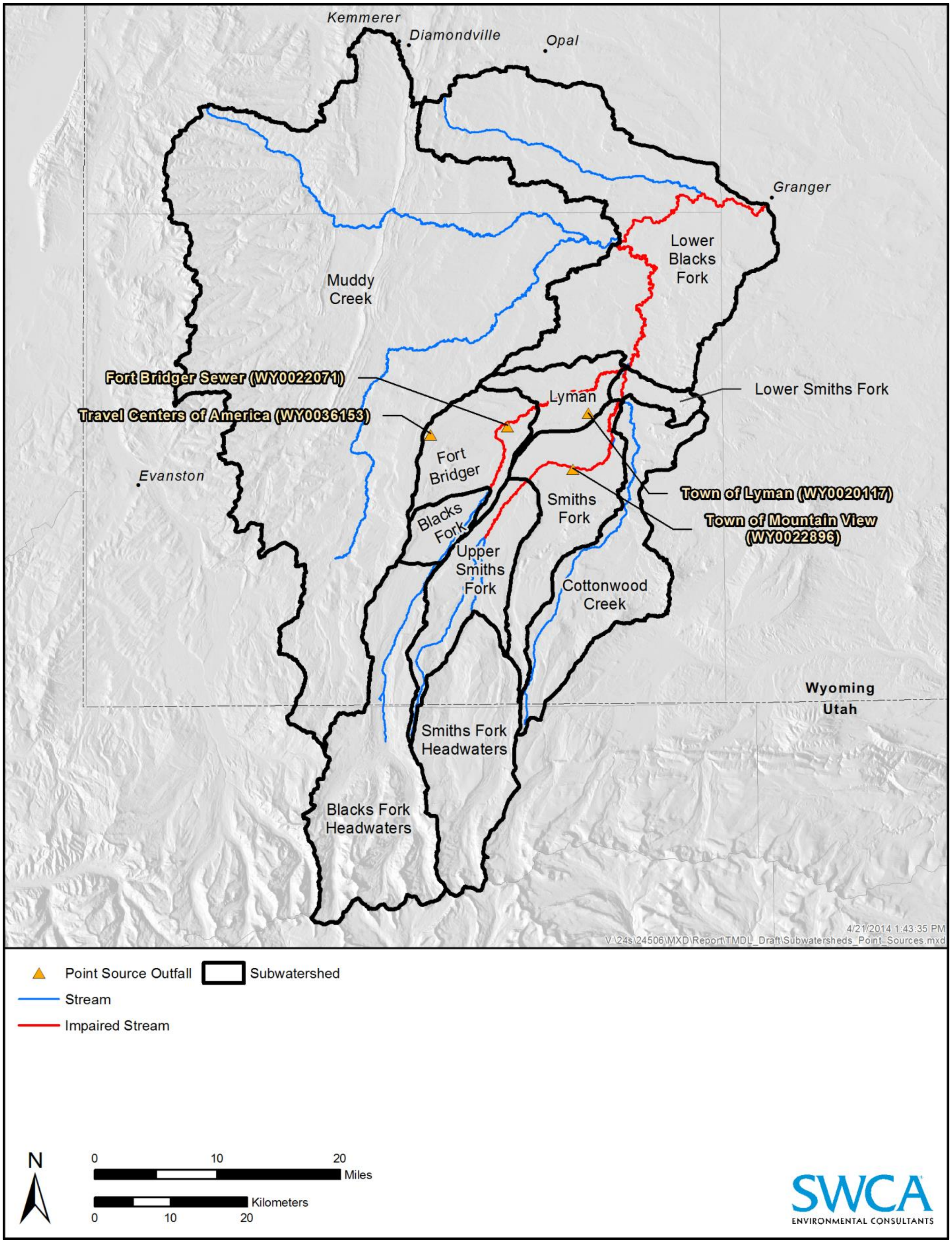

Figure 4.1. Four point source outfalls in the Blacks Fork Watershed.

4.1.1. Fort Bridger Sewer

The Fort Bridger Sewer District operates wastewater lagoons that service 165 connections in the town of Fort Bridger. Wastewater is discharged to an unnamed drainage ditch that is tributary to the Blacks Fork River in the Fort Bridger subwatershed. Typically, irrigation flows or precipitation are needed to transport effluent to the river. The lagoons include an aerated cell followed by a non-aerated cell with chlorination used for disinfection. The facility currently treats 0.14 million gallons per day (MGD), with a design capacity of 0.30 MGD and a permitted *E. coli* concentration of 126 cfu/100 mL. Discharge monitoring data and operational details for this facility were provided by the WDEQ and include monthly geomean values for *E. coli* from 2003 through 2011. The current permit, WYPDES WY0022071, was issued on January 18, 2012. The treatment plant typically operates well below the permitted *E. coli* load under all climate conditions and has exhibited only two *E. coli* concentration exceedances since 2003. In June 2006, the reported concentration was 380 cfu/100 mL and in April 2010, the concentration peaked at 1,534 cfu/100 mL.

4.1.2. Town of Lyman

The Lyman Wastewater Lagoon serves the town of Lyman in Uinta County, Wyoming. The facility has a design capacity of 0.495 MGD and a permitted *E. coli* concentration of 126 cfu/100 mL. It consists of a three-cell lagoon system, in which the first two cells are aerated. Wastewater passes through a chlorine contact chamber before discharging into Lyman Draw via an unnamed ephemeral tributary to the Blacks Fork River in the Lyman subwatershed. Discharge monitoring data for this facility and operational details were provided by the WDEQ and include monthly geomean values for *E. coli* from 2003 through 2011.The current permit, WYPDES WY0020117, was issued on August 31, 2012. Discharge monitoring report data show that Lyman has discharged effluent with concentrations above what is permitted. For six of the nine hydrologic regimes, average *E. coli* concentrations are above 126 cfu/100 mL, with the highest average value of 483 cfu/100 mL occurring during a summer-dry regime. The Lyman Wastewater Lagoon is working with the WDEQ to mitigate effluent *E. coli* concentrations, which exceed the permitted allowance. Doing so will be necessary to comply with the wasteload allocation (WLA).

4.1.3. Town of Mountain View

The Mountain View Wastewater Lagoon in the Smiths Fork subwatershed serves a population of 1,286 people (U.S. Census Bureau 2010) in the town of Mountain View, Wyoming. The facility previously consisted of a three-cell lagoon system in which the first two cells were aerated with SolarBees and chlorination treatment was employed. In August 2012, a new facility was constructed with a design capacity of 0.34 MGD and a permitted *E. coli* concentration of 126 cfu/100mL; here, wastewater flows through automatically operated coarse screening and then to an anaerobic treatment cell followed by complete and partial mix cells and a settling cell. Effluent then flows to a submerged aerated growth reactor. Lastly, the effluent is chlorinated, dechlorinated, and discharged directly into Smiths Fork River. Discharge monitoring data and operational details for this facility were provided by the WDEQ and include monthly averages for *E. coli* from 2003 through 2011. Available data since construction of the new plant (September 2012–December 2013) show monthly average *E. coli* concentrations that range from 1 cfu/100 mL to 980 cfu/100 mL. The current permit, WYPDES WY0022896, was issued on October 2, 2013. The source identification calculations are based on the full data set from 2003 to 2011 to match with the available water quality data used in the analysis. Recent upgrades to the Mountain View Wastewater Lagoon system are reflected in the implementation plan for the watershed.

4.1.4. Travel Centers of America

Travel Centers of America is a truck stop/refueling plaza off Interstate 80 near the town of Fort Bridger, Wyoming. The facility is not connected to any municipal wastewater treatment system; however, it does consist of a three-cell stabilization pond system with an aerated first cell and tablet chlorination following the second cell. Treated effluent flows into a human-made contained wetland that is not tributary to any other surface waters. Although the facility has not discharged since April 2005, it is included as a point source because it is in the Fort Bridger subwatershed and has the potential to affect historical loads. The current permit, WYPDES WY0036153, was issued on November 1, 2010.

4.1.5. Summary of Point Source Load

Across all hydrologic regimes, point source loads are generally small, remaining under 200 G-cfu/season (Figure 4.2, Table 4.1). A season is defined as a 60-day period in spring, summer, or fall. The towns of Mountain View and Lyman typically discharge higher loads than Fort Bridger, with Mountain View exhibiting peak discharge loads in spring and fall of a wet climate year due to high *E. coli* concentrations. Recent upgrades to the Mountain View Wastewater Lagoon will mitigate the high loads observed below. When compared to total loads, Fort Bridger and Smiths Fork subwatersheds contribute negligibly, with only a 2% maximum contribution. Loads in the Lyman subwatershed are comparatively higher, contributing up to 5% of the total load during the dry-fall hydrologic regime.

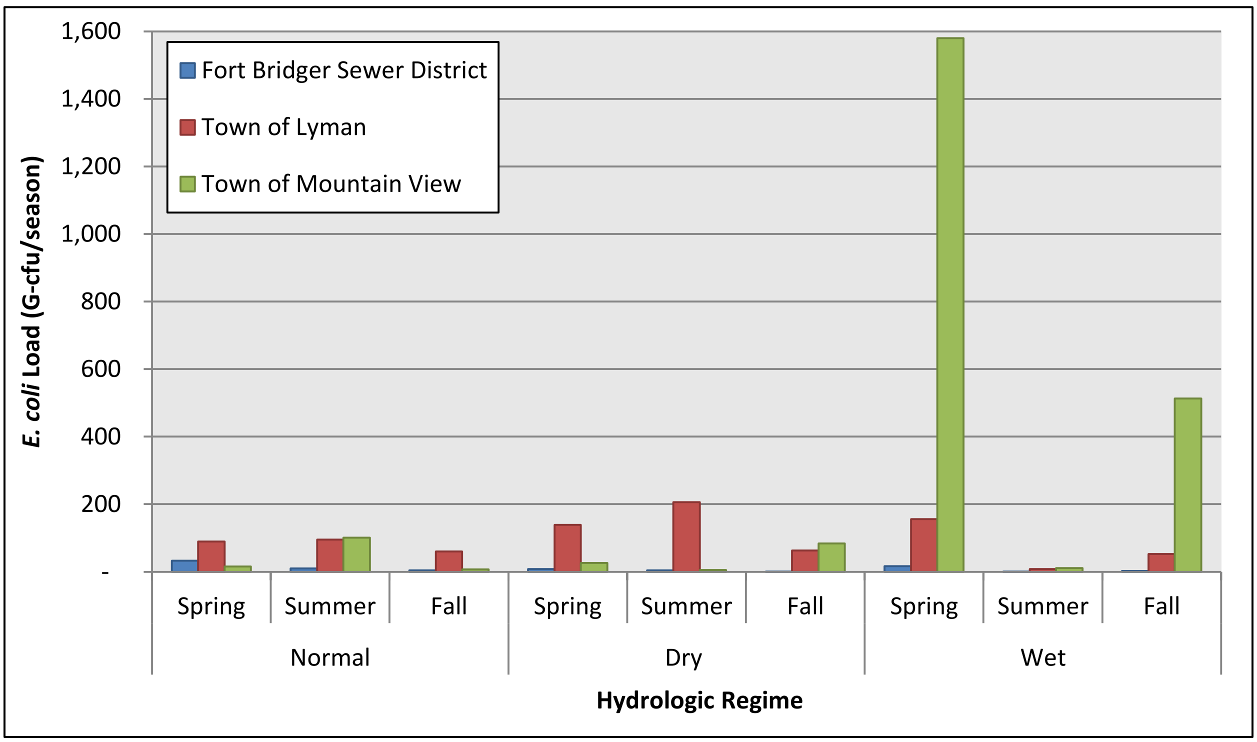

Figure 4.2. Seasonal point source loads from the three wastewater treatment plants in the Blacks Fork Watershed.

Table 4.1. Point Source Loads (G-cfu/season) in the Fort Bridger, Lyman, and Smiths Fork Subwatersheds during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed		
Climate	**Season**	**Fort Bridger**	**Lyman**	**Smiths Fork**
Normal	Spring	35	90	15
	Summer	13	95	101
	Fall	6	60	7
Dry	Spring	11	139	26
	Summer	7	206	5
	Fall	2	63	84
Wet	Spring	20	156	1,579
	Summer	4	8	11
	Fall	4	52	513

4.2. Nonpoint Sources

Nonpoint source pollution originates from many diffuse sources across the landscape. In the Blacks Fork Watershed, nonpoint sources include agricultural practices such as livestock grazing and irrigation on both public and private land, wildlife, septic systems, and pet waste. Restoring water quality and protecting beneficial uses will involve describing and addressing each of these sources individually and applying an appropriate set of implementation measures. Nonpoint sources are not regulated; therefore, all efforts to reduce nonpoint source contribution are voluntary. The following nonpoint source load descriptions are based on seasonal loads occurring during the impairment season (May–September), which are further differentiated into nine hydrologic regimes. *E. coli* load production from livestock, wildlife, septic systems, and pet waste was generated using the bacteria source load calculator (BSLC), a detailed description of which can be found in Appendix A.

4.2.1. Irrigation

Irrigation practices are widespread throughout the Blacks Fork Watershed (Figure 4.3). There are over 380 points of diversion and approximately 217,720 linear feet of irrigation canals and ditches. This canal network transfers water from Blacks Fork to Upper Smiths Fork via the Bridger Joint Power pipeline, and from Blacks Fork, Lyman, and Fort Bridger subwatersheds to Smiths Fork. There are also interwatershed transfers occurring in Blacks Fork, Lyman, and Fort Bridger subwatersheds. Although only 6% of the total watershed acreage is irrigated, most of the subwatersheds that are impaired for *E. coli* exhibit anywhere from 24% to 50% irrigated acreage (Table 4.2). Subirrigated acreage is also included in this estimate and is defined by the WWDC as lands that appear to be receiving irrigation water (based on aerial imagery analysis) but have no appropriated water right (WWDC 2003). Flood irrigation allows water to flow from a ditch or stream onto the fields directly through a headgate or other diverting works. This method has the potential to flush soil, biomass, manure, and fertilizer off the field and into the ditch or stream.*E. coli* monitoring of selected irrigation canals conducted in September 2013 revealed concentrations ranging from 866 to 1,986 cfu/100 mL. Given these high concentrations and the complexity of irrigation flows throughout the landscape, determining the amount of *E. coli* lost or gained through irrigation diversions and returns is an important component of this TMDL process.

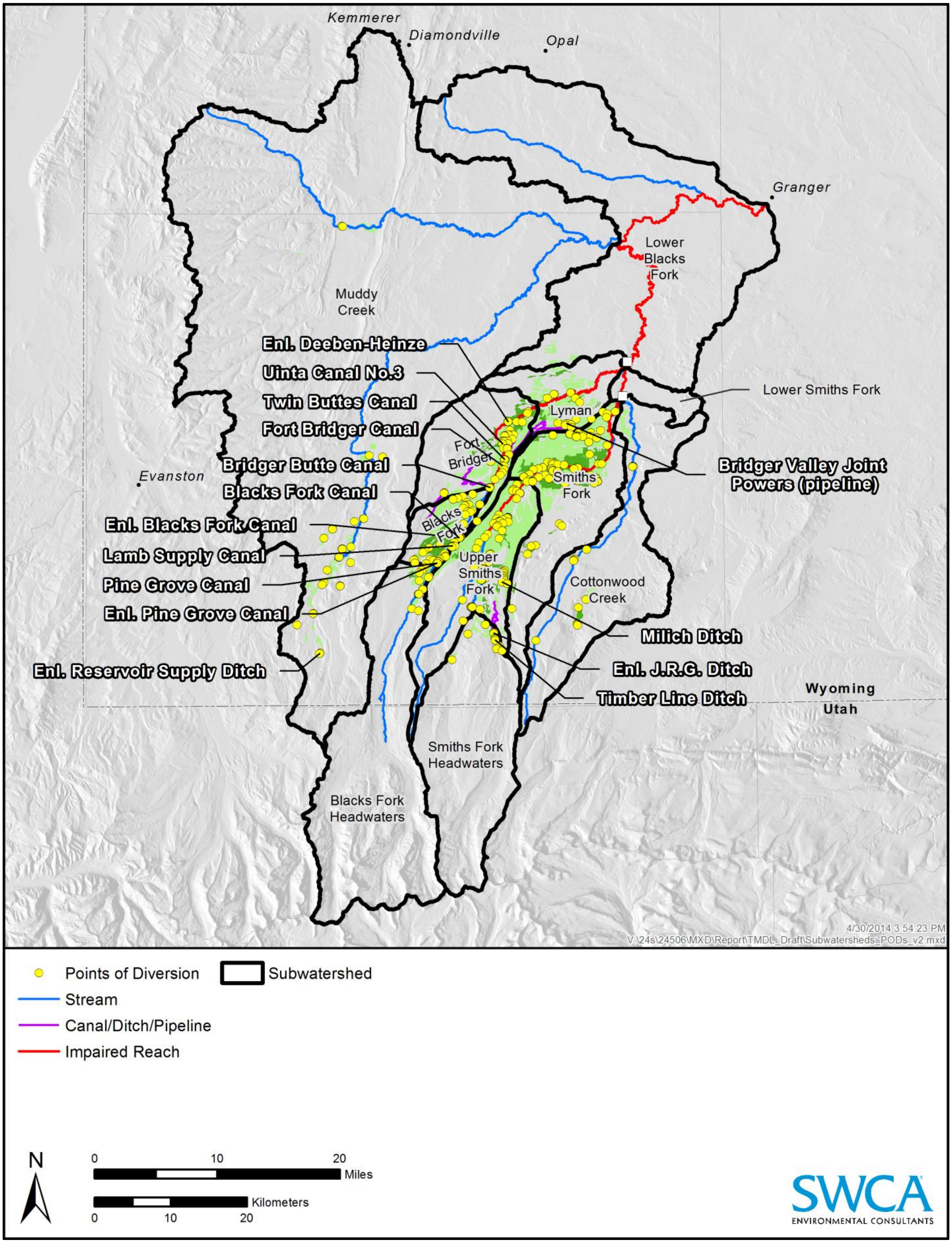

Figure 4.3. Basin-wide location of irrigation canals and points of diversion.

Table 4.2. Percentage of Irrigated and Subirrigated Lands

Subwatershed	Percentage Irrigated	Percentage Subirrigated	Total Irrigated
Blacks Fork Headwaters	1%	< 1%	1%
Blacks Fork	33%	17%	50%
Fort Bridger	19%	5%	24%
Lyman	28%	4%	31%
Smiths Fork Headwaters	1%	0%	1%
Upper Smiths Fork	37%	3%	40%
Smiths Fork	22%	10%	32%
Cottonwood Creek	2%	<1%	2%
Lower Smiths Fork	0%	0%	0%
Muddy Creek	< 1%	0%	< 1%
Lower Blacks Fork	< 1%	0%	< 1%

Note: Subirrigated lands receive irrigation water but have no appropriated water right (Wyoming Water Development Office 2003).

An irrigation load was calculated for each of the 11 subwatersheds and incorporated into the overall load analysis. Irrigation loads were generated by identifying SEO model nodes in each subwatershed where irrigation diversions or returns were occurring (Table 4.3). Diverted and return flows were summed, resulting in a net irrigation flow for each node. The node was then assigned a water quality station or in some cases, an average of two water quality stations where a geomean was calculated using all available *E. coli* data for that hydrologic regime. Diversion flows were assigned water quality stations closest to the point of delivery, whereas return flows were assigned water quality stations from the origin of the diversion. The *E. coli* geomean was multiplied by the net irrigation flow to obtain a load. Irrigation loads were summed by subwatershed to create a seasonal irrigation load for each climate condition. Negative diverted loads indicate a net return of *E. coli* to the subwatershed.

Table 4.3. Model Node and Monitoring Site used to Calculate Diverted Loads for each Subwatershed

Subwatershed	Irrigation Flows	Model Node	Monitoring Site
Blacks Fork Headwaters	None	1.08	BF10
Blacks Fork	Yes	1.12	BF10
	Yes	1.13	BF10
	Yes	1.14	BF10
	Yes	1.16	BF8
Fort Bridger	Yes	1.18	Average BF8/BF7
	Yes	1.20	Average BF8/BF7
	Yes	1.22	Average BF7/BF5
	None	1.24	BF5
Lyman	Yes	1.26	Average BF8/BF7
Smiths Fork Headwaters	None	4.01	BF10

Table 4.3. Model Node and Monitoring Site used to Calculate Diverted Loads for each Subwatershed

Subwatershed	Irrigation Flows	Model Node	Monitoring Site
Upper Smiths Fork	Yes	4.04	SF5
	Yes	4.06	Average SF5/SF4
	Yes	4.08	SF4
Smiths Fork	Yes	4.1	Average BF7/BF5
Lower Smiths Fork	None	6.02	SF1
Cottonwood Creek	Yes	5.04	CC1
Lower Blacks Fork	Yes	7.01	BF3
	None	13.01	BF1
Muddy Creek	None	10.02	CC1

Irrigation loads are presented in Table 4.4 by hydrologic regime. Blacks Fork, Fort Bridger, and Upper Smiths Fork exhibit fairly large net losses of *E. coli* loads through diversions. Contrastingly, Lyman and Smiths Fork subwatersheds exhibit a net gain of *E. coli* on account of irrigation returns. Depending on the hydrologic regime, returns can account for up to 95% of the total load in Lyman (Figure 4.4) and 32% of the total load in Smiths Fork (Figure 4.5).

Table 4.4. Irrigation Loads (G-cfu/season) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed										
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	–	877	6,673	-1,266	–	8,745	-1,290	10	–	–	163
	Summer	–	3,507	21,869	-3,805	–	2,700	-15,307	–	–	–	86
	Fall	–	584	2,041	-334	–	656	-2,599	–	–	–	13
Dry	Spring	–	758	6,310	-445	–	10,200	-2,047	11	–	–	1,508
	Summer	–	2,887	2,231	-3,708	–	4,651	-7,494	–	–	–	33
	Fall	–	371	811	-735	–	1,390	-1,826	–	–	–	12
Wet	Spring	–	2,349	1,620	-540	–	8,530	-1,532	9	–	–	–
	Summer	–	3,679	24,052	-3,135	–	16,057	-6,915	–	–	–	103
	Fall	–	760	1,769	-878	–	2,510	-2,505	–	–	–	29

Note: Negative numbers indicate a net return or delivery of *E. coli* to the subwatershed; positive numbers indicate a net loss of *E. coli* from the subwatershed.

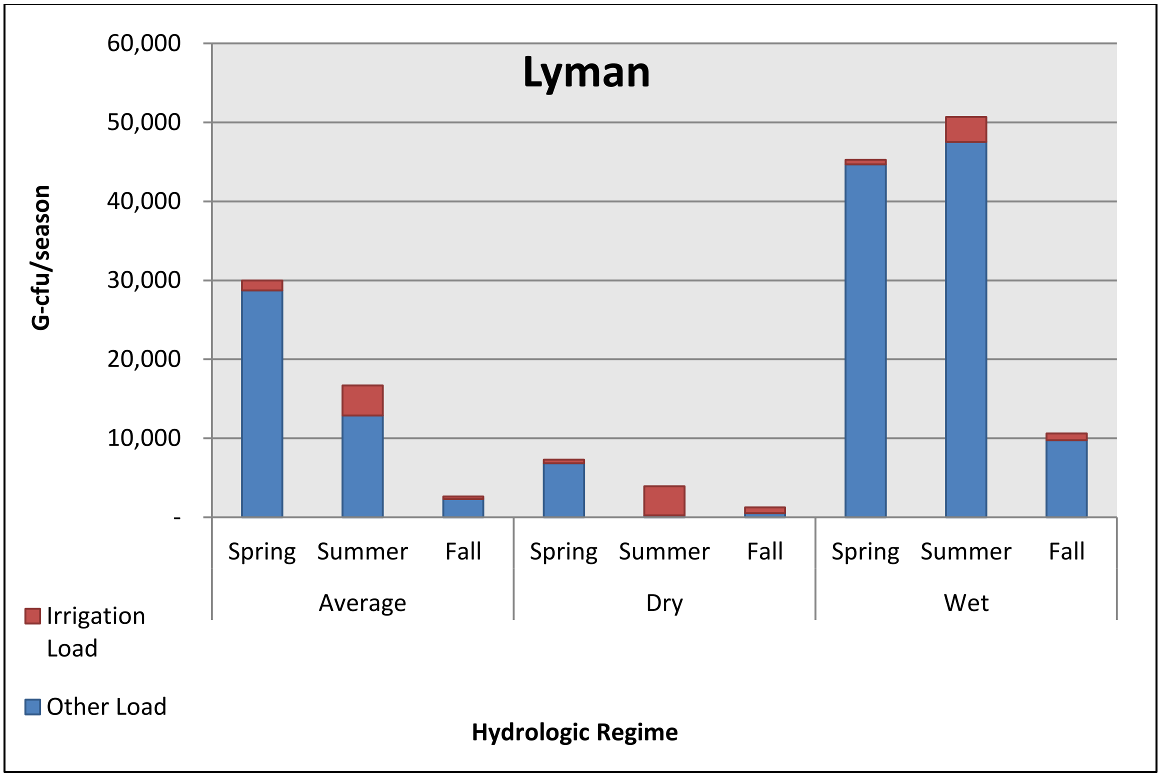

Figure 4.4. Irrigation load proportional to the current total load in the Lyman subwatershed.

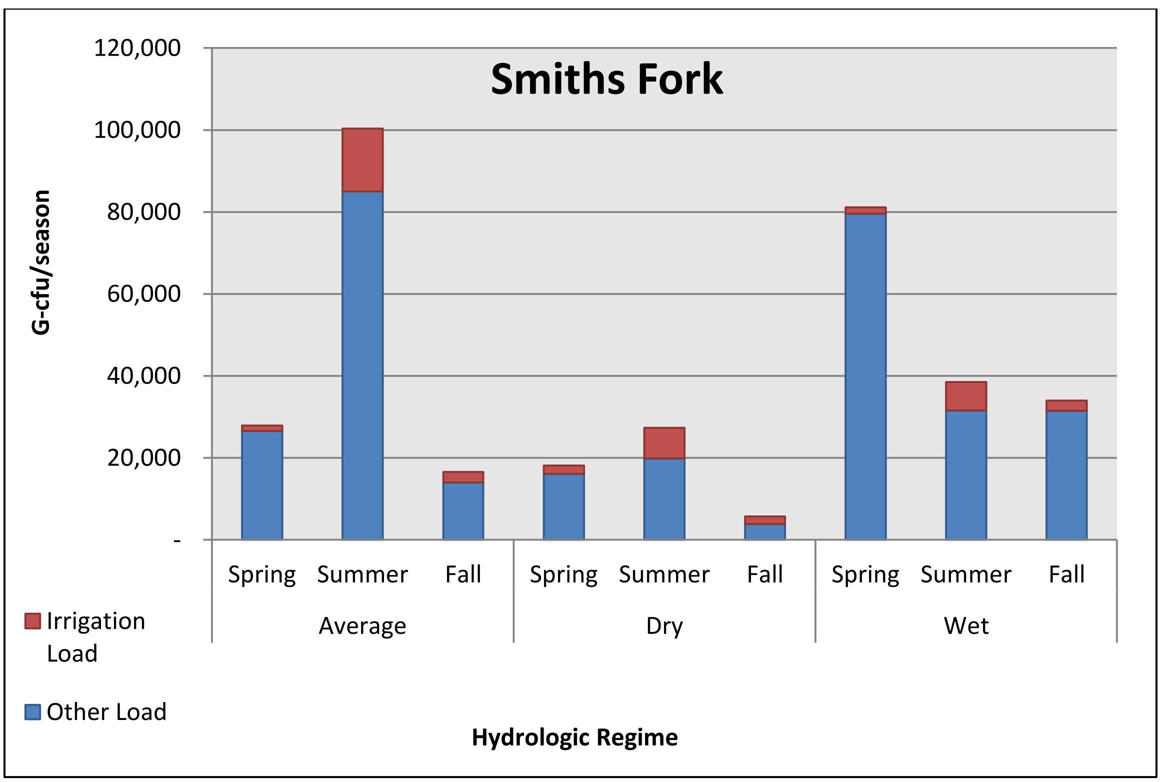

Figure 4.5. Irrigation load proportional to the current total load in the Smiths Fork subwatershed.

4.2.2. Upstream

Accurately quantifying the loading of *E. coli* from activities in each subwatershed requires accounting for the load entering the subwatershed from upstream. A subwatershed with a proportionally large upstream load indicates that *E. coli* is not necessarily originating in the landscape but is being sourced from upstream. Upstream loads for each subwatershed during the nine hydrologic regimes are presented in Table 4.5. These loads were calculated taking into account *E. coli* population variations during surface water transit (see section 4.2.2.1). When compared to total load during a normal climate condition, upstream loads to Lyman, Smiths Fork, and Lower Smiths Fork subwatersheds can contribute a large portion depending on the season (Figure 4.6). The upstream load in Lower Smiths Fork is consistently above 60% of the total load across all seasons and can be as high as 90% of the total load during the summer and fall.

Table 4.5. Seasonal Upstream Loads (G-cfu/season) during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed										
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	–	803	1,106	9,805	–	–	23,823	–	27,887	–	1,095
	Summer	–	2,683	-	10,429	–	–	5,390	–	2,175	–	183
	Fall	–	317	480	1,161	–	–	2,279	–	6,540	–	28
Dry	Spring	–	511	1,267	3,094	–	–	9,114	–	13,147	–	3,121
	Summer	–	1,734	1,478	909	–	–	3,347	–	20,879	–	91
	Fall	–	132	383	202	–	–	1,388	–	5,688	–	40
Wet	Spring	–	3,047	11,374	12,090	–	52	51,934	–	71,381	–	1,977
	Summer	–	4,382	37,380	30,977	–	–	29,147	–	38,485	–	456
	Fall	–	642	5,099	5,098	–	–	5,557	–	29,111	–	93

Note: Loads include survival rate.

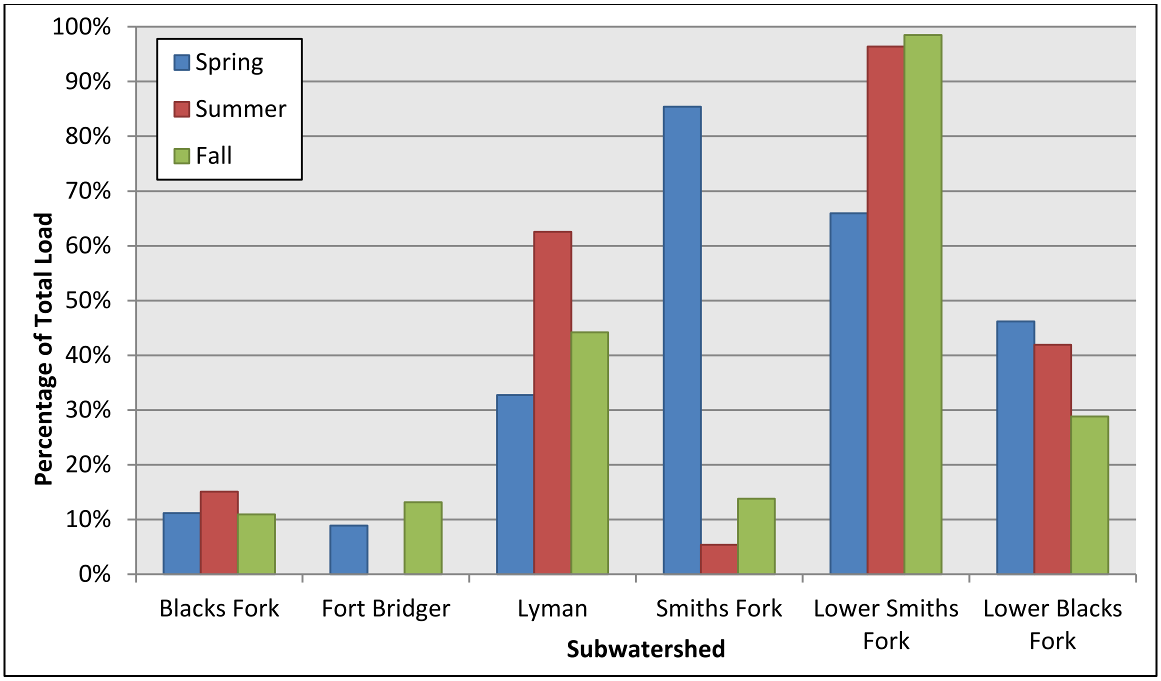

Figure 4.6. Seasonal upstream loads as a percentage of total load in subwatersheds during the normal climate condition.

4.2.2.1. *E. COLI* DECAY AND SURVIVAL

E. coli concentrations are known to decay over time due to die-off, breakdown of cellular structure due to ultraviolet radiation from sunlight, predation, dispersion, adsorption to particles, and settling (Mitchell and Chamberlin 1978; EPA 1985; Flint 1987). In their synthesis of available literature at the time, Mitchell and Chamberlin (1978) suggest that settling may be responsible for the most significant fraction of observed decay due to the relatively large settling velocities of *E. coli*. Although the mechanisms of decay and regeneration of *E. coli* are complex, their collective influence can be approximately modeled with a simple first-order decay function:

$$\frac{dC}{dt} = -kC$$

or

$$C_t = C_0 e^{-kt}$$

Where C_0 = initial coliform concentration [most probable number (MPN)]
C_t = coliform concentration at time t [MPN]
k = overall decay rate [d^{-1}]
C = coliform concentration [MPN]
t = exposure time [d]

Therefore, with an initial concentration and knowledge of the overall decay rate, a downstream *E. coli* concentration can be predicted. The overall decay rate is largely affected by temperature, and this relationship can be approximated with the following equation (Mancini 1978):

$$k_T = k_{20} \times \theta^{(T-20)}$$

Where k_T = overall decay rate at temperature T (°C) [d^{-1}]
k_{20} = overall decay rate at 20°C [d^{-1}]
θ = temperature correction factor [1.07]
T = temperature [°C]

K_{20} varies widely between watersheds, but the values found in the literature range from 0.1 and 2.0 d^{-1} (Crane and Moore 1986). Because available data for k_{20} were not available for Blacks Fork and Smiths Fork reaches, an assumed median value of 1 d^{-1} was used. The temperature correction equation was used to determine overall decay rates for all of the modeling periods under consideration, where the temperature used in the equation (T) was the average water temperature for each time period and location. This approach yielded an overall decay rate range of 0.21–0.86 d^{-1} (Table 4.5). This range of values was then applied over exposure times for each reach (calculated from reach velocities and lengths) to yield survival rates in each reach.

Table 4.5. Decay Rates (d^{-1}) used for the Nine Hydrologic Regimes

Hydrologic Regime		**Subwatershed**										
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	Spring	0.29	0.37	0.46	0.43	0.29	0.37	0.46	–	0.40	–	0.50
	Summer	0.58	0.58	0.63	0.54	0.58	0.63	0.58	–	0.63	–	0.21
	Fall	0.46	0.46	0.50	0.46	0.46	0.50	0.50	–	0.40	–	0.21
Dry	Spring	0.37	0.37	0.54	0.43	0.37	0.43	0.46	–	0.43	–	0.74
	Summer	0.63	0.68	0.74	0.63	0.63	0.63	0.74	–	0.63	–	0.21
	Fall	0.54	0.46	0.54	0.46	0.54	0.46	0.40	–	0.40	–	0.21
Wet	Spring	0.25	0.29	0.32	0.34	0.25	0.29	0.34	–	0.34	–	0.21
	Summer	0.50	0.58	0.79	0.74	0.50	0.63	0.86	–	0.74	–	0.21
	Fall	0.50	0.46	0.58	0.54	0.50	0.46	0.58	–	0.54	–	0.21

4.2.3. Watershed

Calculated point source, irrigation, and upstream loads were summed and subtracted from current loads to determine a watershed load for each subwatershed (Table 4.6). These watershed loads represent the sum of *E. coli* input from nonpoint sources that include livestock, wildlife, septic systems, and pet waste. Figure 4.7 provides a visual of the proportional contribution of watershed loads to total loads and clearly illustrates the importance of watershed load to impairments during a normal climate condition. Watershed loads were further quantified using the BSLC to determine specific loads from livestock, wildlife, septic systems, and pet waste, all of which will be discussed in detail below. The BSLC modeling methodology can be found in Appendix A.

Table 4.6. Watershed Loads (G-cfu/season) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed										
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	Spring	1,783	6,383	11,333	18,821	605	72,297	2,760	80	14,419	188	1,276
	Summer	6,611	15,118	15,828	2,350	1,724	7,451	79,556	16	1,575	18	253
	Fall	955	2,587	3,164	1,072	273	3,008	11,687	4	101	3	68
Dry	Spring	1,316	8,698	2,833	3,594	328	13,743	6,932	18	299	16	12,612
	Summer	5,012	13,187	157	0	1,223	5,034	16,538	3	836	4	149
	Fall	532	1,881	51	236	125	1,731	2,390	1	1,503	2	39
Wet	Spring	5,901	11,841	2,878	32,456	2,917	65,544	26,106	200	4,746	432	11,201
	Summer	8,644	80,345	12,873	16,558	3,092	80,169	2,412	50	70,667	41	3,257
	Fall	1,489	8,892	1,563	4,598	554	7,473	25,417	10	1,373	13	600

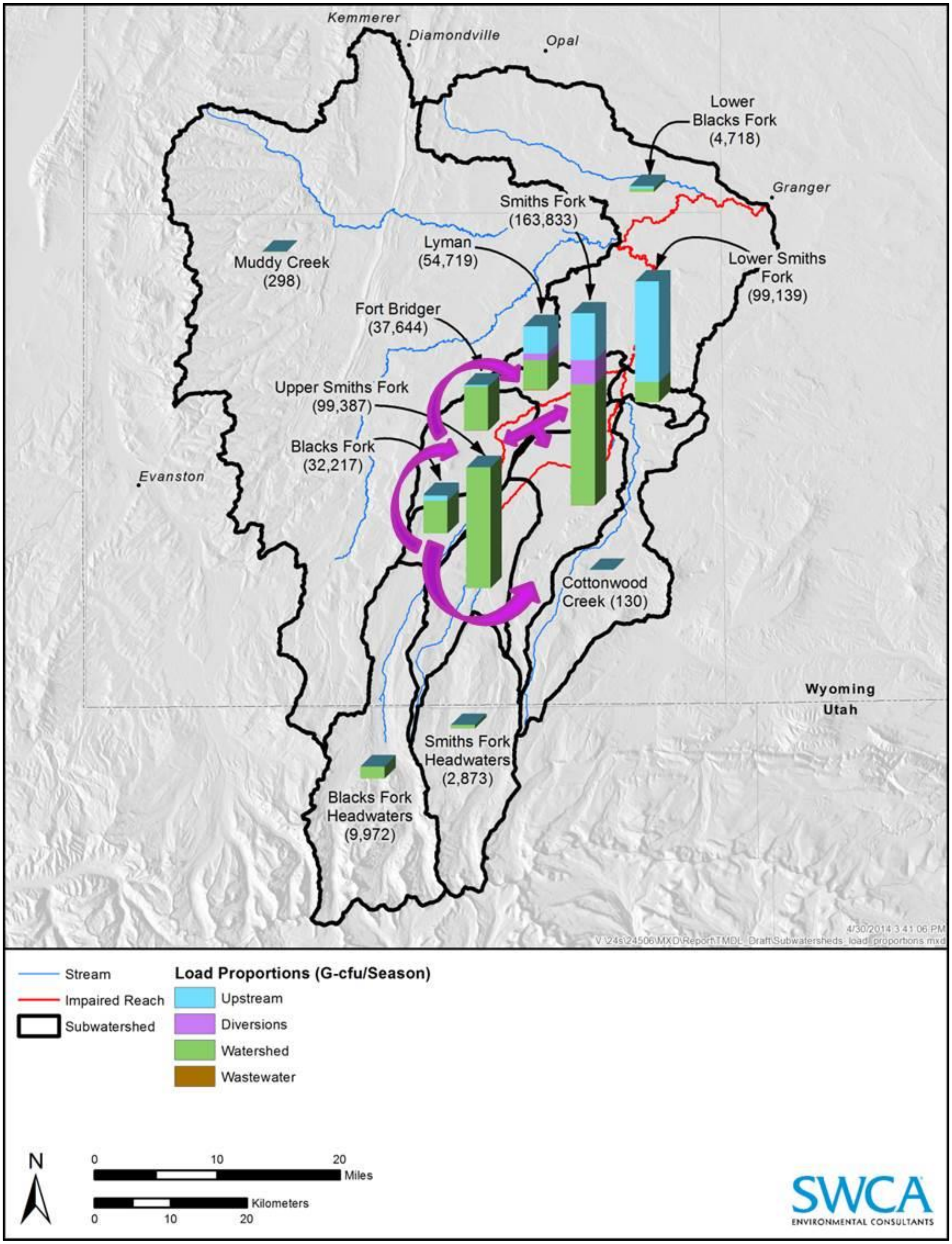

Figure 4.7. Load proportions for each subwatershed during the normal climate condition. Arrows indicate transfer of water between subwatersheds via irrigation infastructure and are not drawn to scale.

4.2.3.1. LIVESTOCK

Livestock grazing is present throughout the Blacks Fork Watershed and is an important *E. coli* source to characterize for the TMDL analysis. Understanding population sizes, locations, and seasonal movements and how they relate to spatial and temporal impairment trends is important for identifying problem areas and implementing effective mitigation measures. In addition to providing direct pathogen inputs to a stream, animal excrement deposited on the landscape can wash into streams or canals during storm events or during irrigation flooding. In addition, livestock can also cause soil compaction and degrade riparian areas, leading to greater surface runoff during spring melt and storms. Livestock populations in the Blacks Fork Watershed were estimated using several approaches to further understand population numbers for each subwatershed and how they transition on a monthly basis.

4.2.3.1.1. Total Livestock

Estimating livestock numbers on both public and private land throughout the Blacks Fork Watershed was conducted using the 2007 Census of Agriculture county profiles for Uinta, Summit, and Lincoln Counties, Wyoming (U.S. Department of Agriculture [USDA] 2009). The county profiles provided population estimates for cattle and calves, sheep and lambs, horses, and goats. These countywide numbers were scaled based on the total acreage in each subwatershed that intersected with Uinta, Summit, or Lincoln County.

Findings are expressed in animal units. *Animal units* are defined by the BLM as a unit of measure for rangeland livestock equivalent to one mature cow, which typically consumes an average of 26 pounds of dry matter per day (BLM 2011). Converting livestock numbers to animal units required the use of an animal unit equivalent (AUE) conversion factor. For cows, AUE is 1; for sheep, AUE is 0.21; for horses, AUE is 1.25; and for goats, AUE is 0.15 (Pratt and Rasmussen 2001).

Cattle account for 80% of total animal units in the Blacks Fork Watershed, followed by sheep at approximately 15% (Figure 4.8). The highest total population for all species resides in the Muddy Creek subwatershed followed by Lower Blacks Fork (Table 4.7). Total livestock for the entire watershed is estimated to be 46,461 animal units.

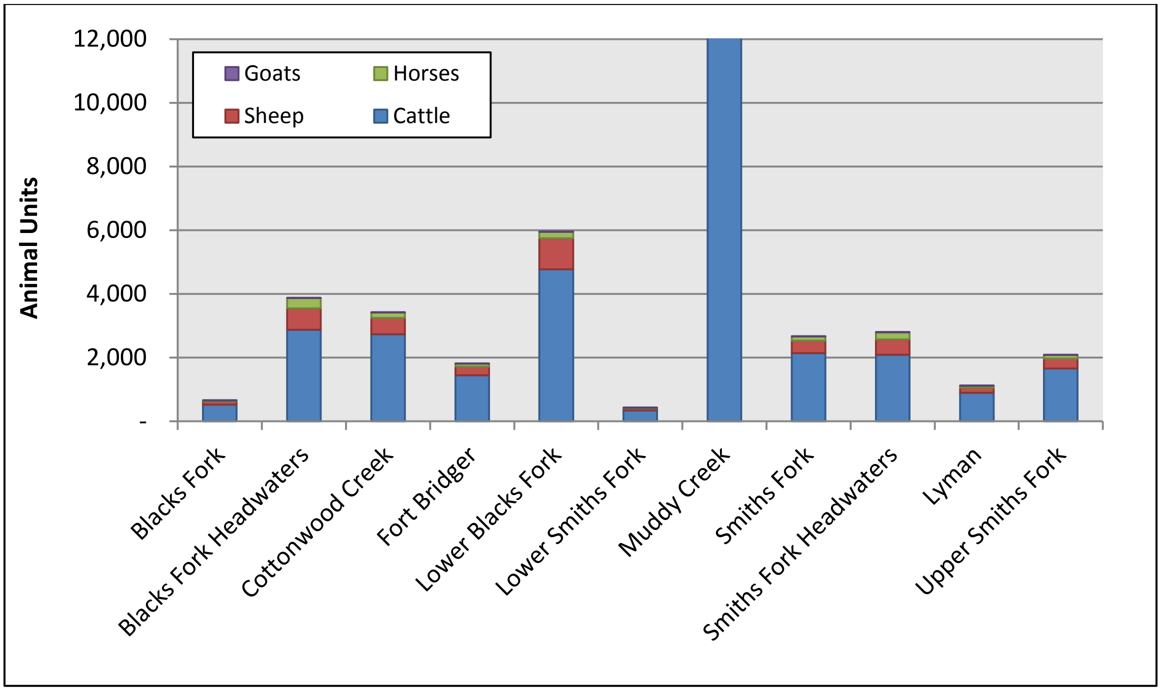

Figure 4.8. Animal units by species for each subwatershed.

Table 4.7. Livestock Estimates in Animal Units for each Subwatershed for Cattle, Sheep, Horses, and Goats

Subwatershed	Cattle	Sheep	Horses	Goats	Total
Blacks Fork	528	98	33	1	660
Blacks Fork Headwaters	2,879	672	322	6	3,879
Cottonwood Creek	2,734	507	172	4	3,417
Fort Bridger	1,451	269	91	2	1,813
Lower Blacks Fork	4,776	966	210	6	5,958
Lower Smiths Fork	338	63	21	0	422
Muddy Creek	17,339	3,331	958	24	21,652
Smiths Fork	2,137	396	134	3	2,670
Smiths Fork Headwaters	2,092	478	223	4	2,797
Lyman	891	165	56	1	1,113
Upper Smiths Fork	1,663	308	105	2	2,078
Total	**36,827**	**7,252**	**2,325**	**53**	**46,459**

4.2.3.1.2. Grazing on Public Land

Public land grazing in the Blacks Fork Watershed has the potential to contribute a large source of pathogens to waterways because it represents 88% of the total watershed acreage. The BLM has 107 grazing allotments in the northern regions of the watershed, and the USFS has seven active allotments throughout the Blacks Fork and Smiths Fork Headwaters, Cottonwood Creek, and Muddy Creek subwatersheds (Figure 4.9). Allotment leases provide data on both the number of livestock using the land as well as the time period in which they reside, allowing for monthly estimations throughout a year.

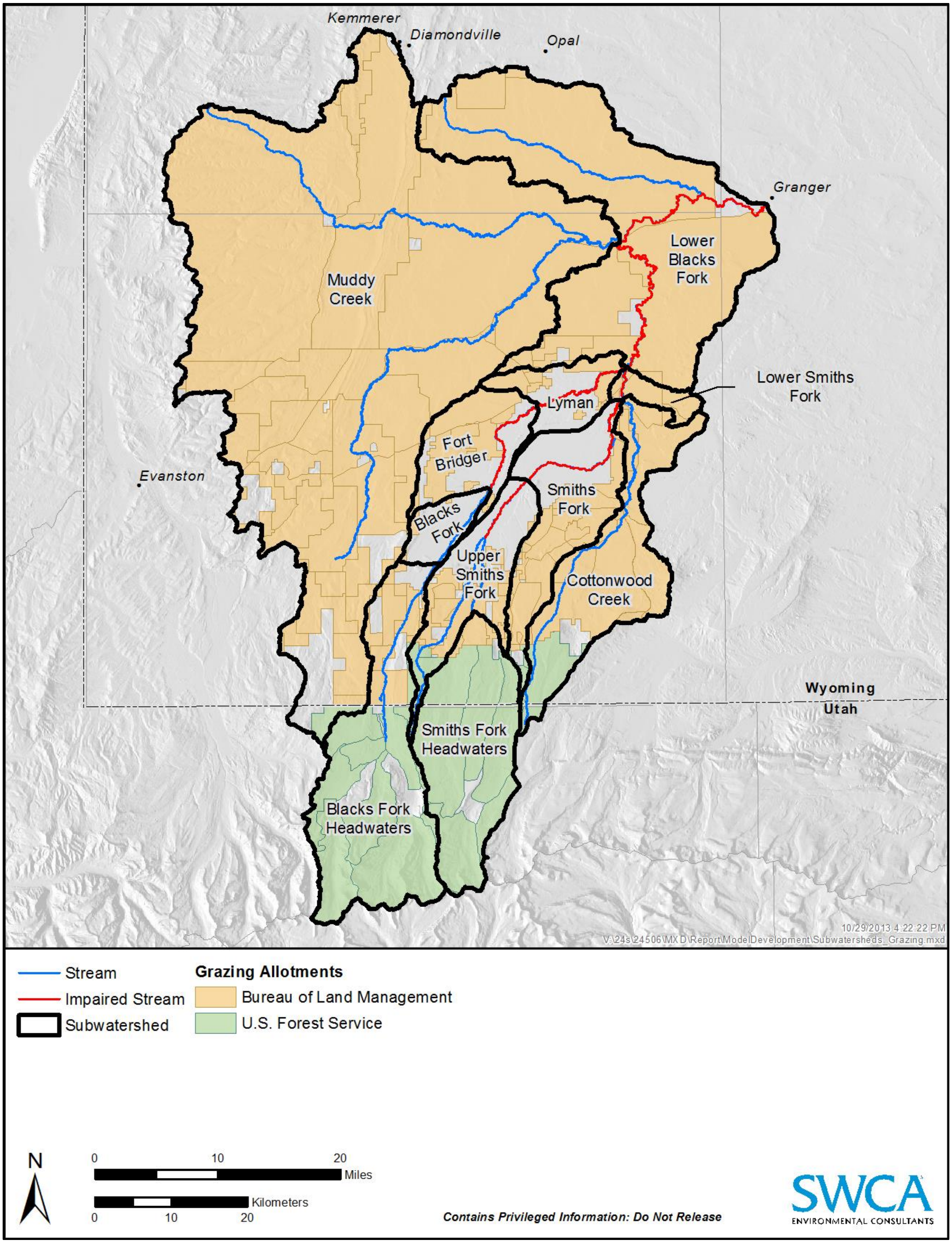

Figure 4.9. Publicly administered grazing allotments by subwatershed.

The livestock estimation analysis was conducted for both cattle and sheep. Populations by subwatershed were generated by scaling total allotment populations by the amount of allotment acreage that intersected with the subwatershed. For example:

$$\text{Blacks Fork subwatershed cattle} = \frac{\text{total allotment cattle} \times \text{allotment acreage in Blacks Fork}}{\text{total allotment acreage}}$$

Grazing on USFS allotments is concentrated in the Blacks Fork Headwaters and Smiths Fork Headwaters subwatershed primarily during the summer month (June–September) (Table 4.8). Grazing on BLM allotments is much more complex. Populations can vary dramatically throughout a year as animals are moved from winter pasture to summer grazing and vice versa (Table 4.9). The maximum monthly density of animals that occurs in each subwatershed can be seen in Figure 4.10. Lower Blacks Fork, Lower Smiths Fork, and Muddy Creek have the highest density of livestock, whereas Blacks Fork has the lowest. Maximum density for the entire Blacks Fork Watershed is 0.04 animal per acre and occurs in April.

Table 4.8. Animal Units (cattle and sheep) in U.S. Forest Service Allotments throughout the Year

Subwatershed	January	February	March	April	May	June	July	August	September	October	November	December
Blacks Fork	0	0	0	0	0	0	0	0	0	0	0	0
Blacks Fork Headwaters	0	0	0	0	0	205	435	435	230	0	0	0
Cottonwood Creek	0	0	0	0	0	0	8	8	8	0	0	0
Fort Bridger	0	0	0	0	0	0	0	0	0	0	0	0
Lower Blacks Fork	0	0	0	0	0	0	0	0	0	0	0	0
Lower Smiths Fork	0	0	0	0	0	0	0	0	0	0	0	0
Muddy Creek	0	0	0	0	0	85	85	85	0	0	0	0
Smiths Fork	0	0	0	0	0	0	0	0	0	0	0	0
Smiths Fork Headwaters	0	0	0	0	0	0	873	873	873	0	0	0
Lyman	0	0	0	0	0	0	0	0	0	0	0	0
Upper Smiths Fork	0	0	0	0	0	0	0	0	0	0	0	0

Table 4.9. Animal Units (cattle and sheep) in Bureau of Land Management Allotments throughout the Year

Subwatershed	January	February	March	April	May	June	July	August	September	October	November	December
Blacks Fork	1	1	1	1	1	1	1	1	1	1	1	1
Blacks Fork Headwaters	14	14	14	14	68	289	104	104	93	22	16	14
Cottonwood Creek	96	96	95	957	1,098	1,035	1,020	1,043	991	59	49	44
Fort Bridger	3	3	3	3	420	398	144	144	169	133	49	3
Lower Blacks Fork	3,509	3,509	3,505	4,461	2,419	1,736	1,177	889	1,078	417	1,060	3,509
Lower Smiths Fork	124	124	123	190	194	87	87	87	87	27	149	129
Muddy Creek	5,124	5,124	5,117	5,381	13,709	16,674	9,967	8,696	9,933	6,594	2,598	5,276
Smiths Fork	15	15	28	73	434	631	580	563	626	473	38	8
Smiths Fork Headwaters	1	1	1	1	215	440	127	123	181	88	1	1
Lyman	67	67	67	63	160	100	52	52	57	49	80	68
Upper Smiths Fork	4	4	8	8	400	1,096	280	256	352	182	20	8

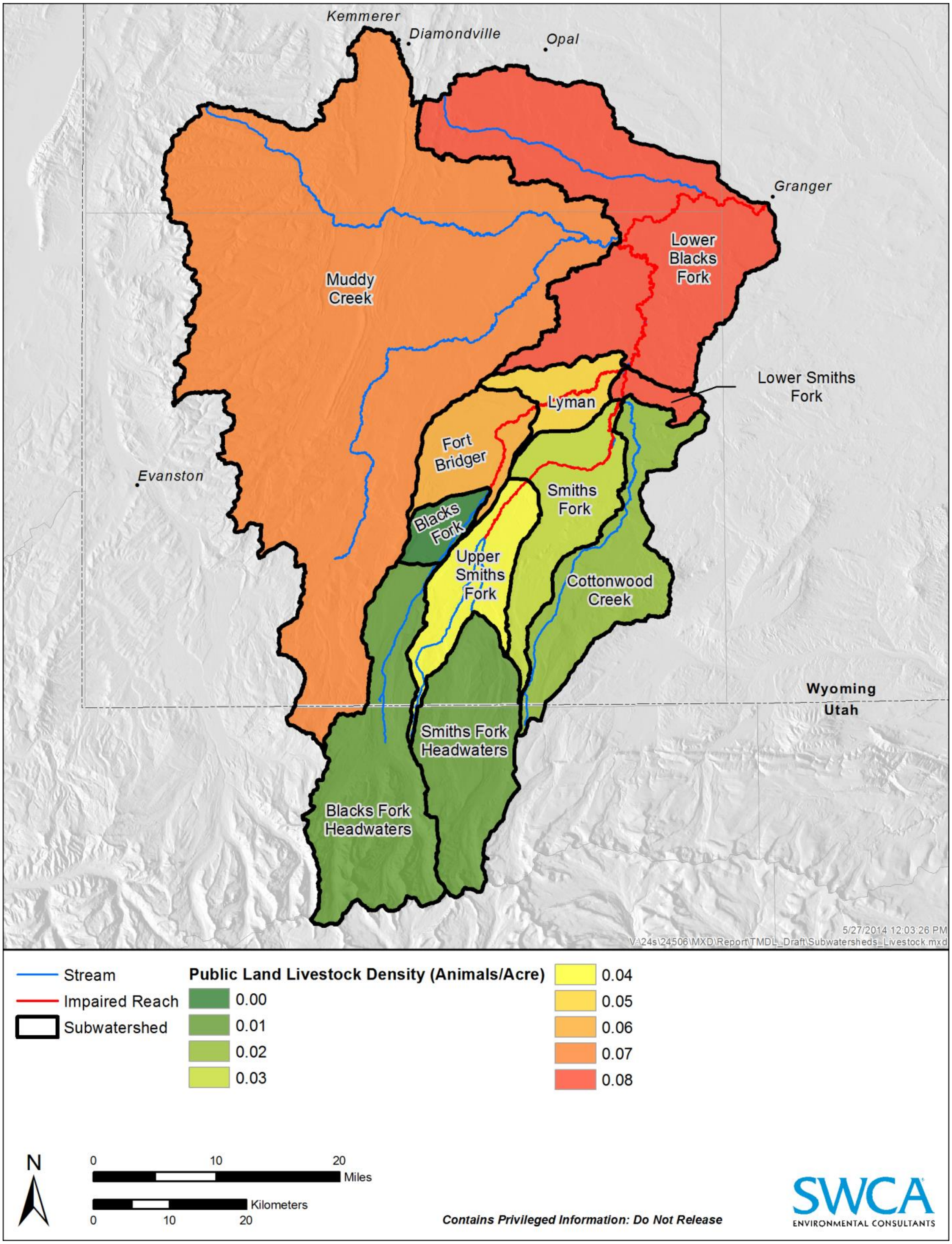

Figure 4.10. Maximum monthly livestock density (cattle and sheep) on public lands (Bureau of Land Management and U.S. Forest Service) for each subwatershed.

4.2.3.1.3. Grazing on Private Land

Seasonal grazing patterns in the Blacks Fork Watershed are complex. Cattle are primarily housed in the inner subwatersheds during the winter and early spring, and are then moved to outer regions during the summer and fall. A portion of cattle is transferred to USFS allotments in the headwaters, whereas others are moved to regions beyond the watershed boundary. Livestock movement from public to private land can create difficulty in estimating the number and seasonality of cattle that reside on private land. As such, generating estimates of grazing on private lands required conducting a manual count of cattle using aerial imagery of private lands intersected with subwatershed boundaries. Figure 4.11 displays private and public landownership in the region and identifies the area of private land that was the focus for conducting counts; this focused private land is circled in red, and public land is shown in purple. Figure 4.12 provides a larger-scale sample of the focused private land (see blue circle). Counts were conducted on private areas in subwatersheds that are either impaired or directly upstream of impaired reaches. Imagery was unavailable for 41% of the private land in the winter and estimates had to be extrapolated to those lands based on counts in the surveyed land. Two counts were conducted during the summer and winter, and populations were estimated by subwatershed (Table 4.10). The summer count was conducted using aerial imagery sourced from USGS during August 2010 and streamed through ArcGIS Explorer. The winter count was conducted using aerial imagery from DigitalGlobe during November 2002 and streamed through Google Earth. The winter imagery covered only a portion of the subwatersheds; therefore, estimates were extrapolated to those private lands not covered. Numbers generated in the counts were extrapolated to other months using grazing patterns identified by stakeholders in the region (Figure 4.13) and combined with grazing allotment data to identify total monthly populations of cattle in each subwatershed (see Table 4.10).

Table 4.10. Seasonal Estimates of Animal Units (cattle only) throughout the Year

Subwatershed	January	February	March	April	May	June	July	August	September	October	November	December
Blacks Fork	5,198	5,198	5,198	5,198	2,047	2,047	2,047	2,047	2,047	2,047	5,198	5,198
Blacks Fork Headwaters	11	11	11	11	65	286	330	330	320	18	13	11
Cottonwood Creek	54	54	54	916	1,056	1,030	1,023	1,046	995	54	2	2
Fort Bridger	3,164	3,164	3,164	3,164	3,316	1,389	1,347	1,347	1,347	1,311	3,164	3,164
Lower Blacks Fork	72	72	72	1,018	961	897	743	743	635	9	72	72
Lower Smiths Fork	7	7	7	74	66	66	66	66	66	7	12	12
Muddy Creek	161	161	161	62	9,955	13,820	7,868	7,953	7,795	4,444	227	313
Smiths Fork	5,200	5,200	5,203	5,203	5,564	4,294	4,244	4,227	4,276	4,191	5,233	5,203
Smiths Fork Headwaters	1	1	1	1	215	433	985	985	1,053	88	1	1
Lyman	3,119	3,119	3,119	3,114	3,162	730	726	726	726	718	3,115	3,119
Upper Smiths Fork	4,860	4,860	4,864	4,864	5,256	3,357	2,542	2,518	2,614	2,444	4,876	4,864
Total	**21,847**	**21,847**	**21,854**	**23,625**	**31,663**	**28,349**	**21,921**	**21,988**	**21,874**	**15,331**	**21,913**	**21,959**

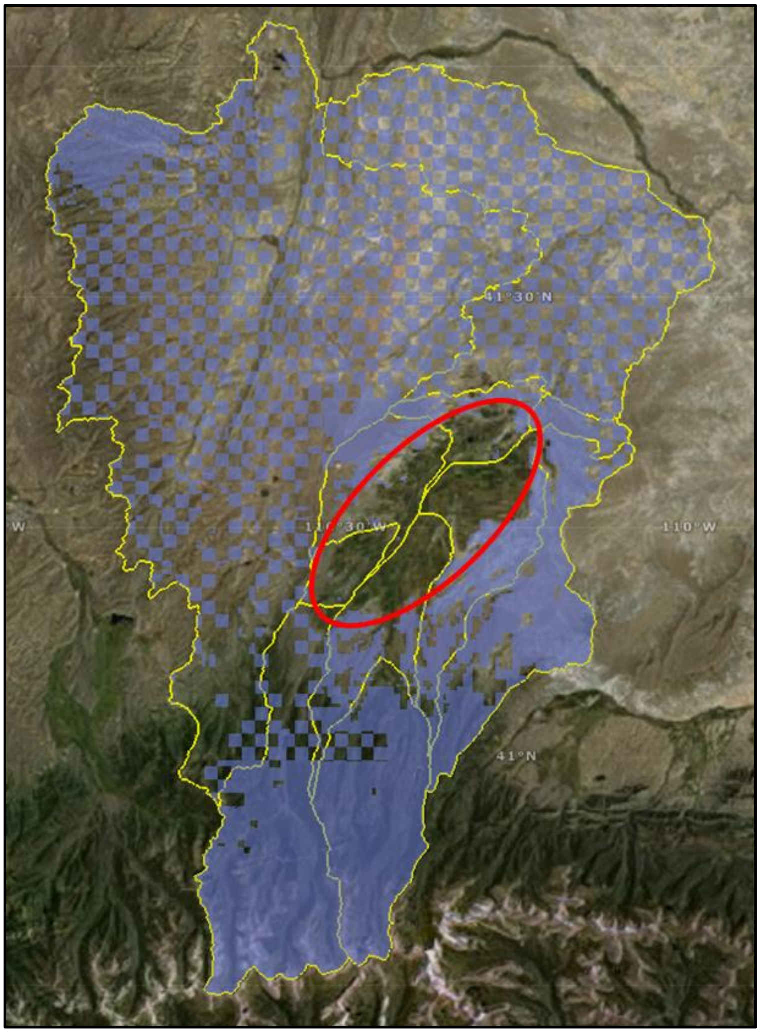

Figure 4.11. Focus area for conducting cattle counts using aerial imagery (purple coloring indicates public landownership; the red circle denotes private land where counts were conducted) (Google Earth Landsat Imagery 2014).

Figure 4.12. Larger-scale sample of the focused private land (see blue circle) (Digital Globe 2002).

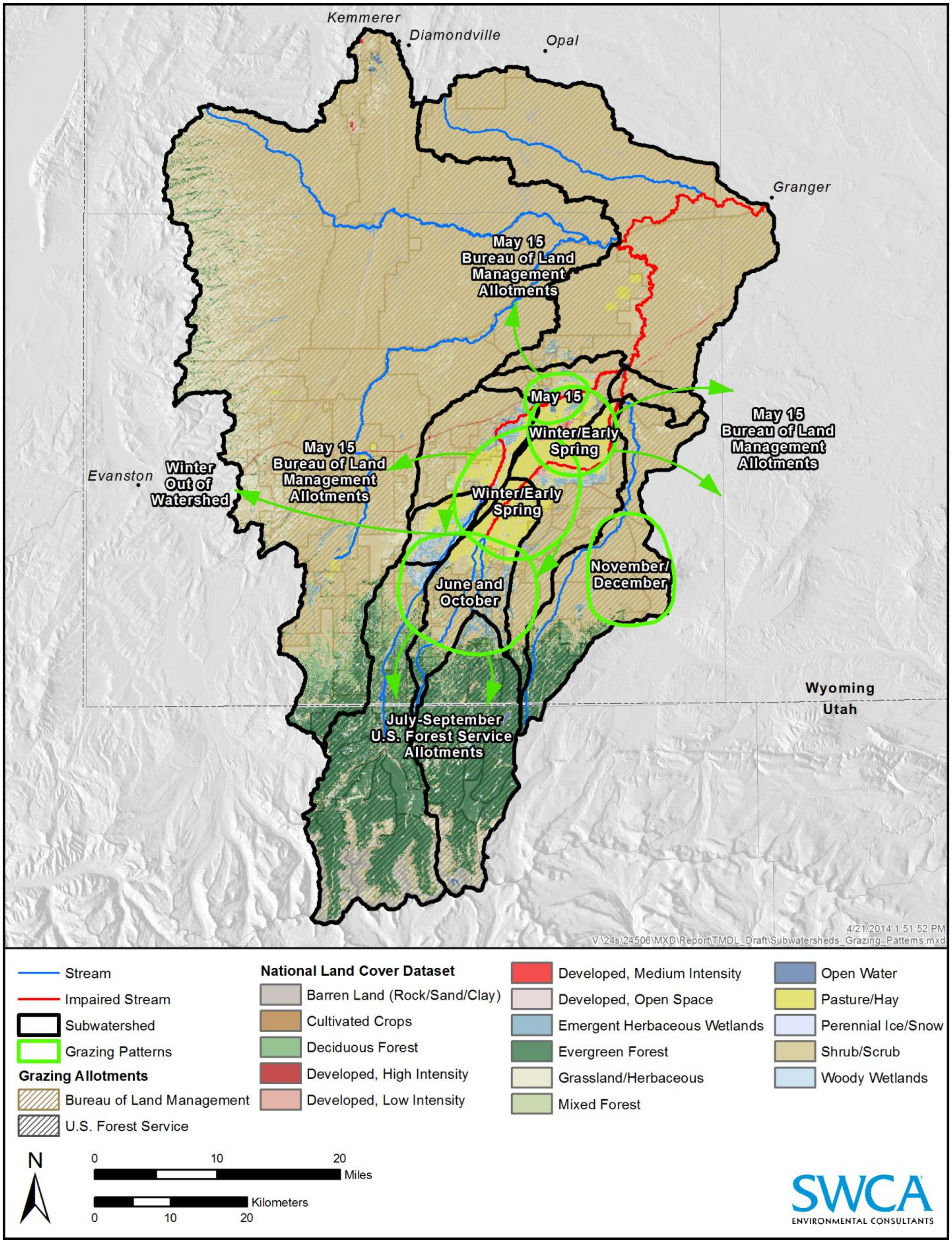

Figure 4.13. Grazing patterns for cattle identified by stakeholders in the Blacks Fork Watershed.

Cattle grazing on private land is primarily concentrated in the Lyman subwatershed during the summer months and is highest in the Blacks Fork and Lyman subwatersheds in the winter months (Table 4.11). Counts indicate that the population more than doubles from summer to winter. In all, 9,983 cattle were found to occupy portions of Blacks Fork, Fort Bridger, Lyman, Upper Smiths Fork, and Smiths Fork subwatersheds during the summer and 21,526 in the winter.

Table 4.11. Seasonal Cattle Estimates on Private Land by Subwatershed

Subwatershed	Summer	Winter
Blacks Fork	2,046	5,197
Fort Bridger	1,257	3,162
Smiths Fork	686	3,113
Lyman	3,732	5,198
Upper Smiths Fork	2,262	4,856
Total	**9,983**	**21,526**

4.2.3.1.4. Livestock Loads

The number of animals residing in the watershed coupled with complex grazing patterns contributes to the *E. coli* loads from livestock in most subwatersheds across all hydrologic regimes (Table 4.12). Cattle are primarily housed in the inner subwatersheds in the winter and early spring, and are then moved to outer regions in the summer and fall. A small portion of cattle is transferred to USFS allotments in the headwaters, whereas others are moved to regions beyond the watershed boundary.

Table 4.12. Livestock Loads (G-cfu/season) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed										
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	303	6,114	10,249	16,770	123	66,828	2,541	59	11,971	162	966
	Summer	3,302	14,480	13,079	1,750	742	6,543	72,331	12	1,114	14	141
	Fall	136	2,477	2,632	801	122	2,652	10,641	4	71	2	40
Dry	Spring	224	8,331	2,562	3,202	67	12,703	6,381	13	248	14	9,549
	Summer	2,503	12,631	130	0	526	4,420	15,036	2	591	3	83
	Fall	76	1,802	42	177	56	1,526	2,176	1	1,062	2	23
Wet	Spring	1,004	11,342	2,603	28,918	593	60,586	24,031	147	3,940	371	8,480
	Summer	4,318	76,956	10,636	12,329	1,331	70,395	2,193	36	49,976	32	1,822
	Fall	213	8,517	1,299	3,436	247	6,588	23,142	10	970	10	357

4.2.3.2. WILDLIFE

Wildlife in the Blacks Fork Watershed has the potential to be a significant source of pathogens to waterways by direct defecation into streams. In addition to direct defecation into streams, wildlife excrement deposited on the landscape can wash into streams or canals during storm events or during irrigation flooding. Therefore estimating populations by subwatersheds and understanding the migratory patterns of species throughout the year are important steps in determining the relevance of this source. The Utah Division of Wildlife Resources and WGFD provided data for moose, deer, elk, and antelope herd units that occupy the Blacks Fork Watershed. Data consisted of both population estimates and seasonal migration patterns for eight herd units. Herd unit area was intersected with subwatershed boundaries to determine the acreage of herd unit area within each subwatershed. Population estimates for each herd unit were then scaled by area to the subwatershed (Table 4.13). Wildlife densities for all four species were also calculated by subwatershed, revealing the highest densities to be in the center of the watershed consisting primarily of deer and antelope (Figure 4.14). In general, deer, elk, and moose tend to occupy the headwaters and Muddy Creek subwatersheds, whereas antelope are more prevalent in the lowlands. Waterfowl was also explored as an additional source using the BSLC and was found to contribute < 1% of the total load (see Appendix A, section 1.3.1).

Table 4.13. Population Estimates for each Subwatershed for Deer, Elk, Moose, and Antelope

Subwatershed	Deer	Elk	Moose	Antelope	Total
Blacks Fork	145	20	2	111	**278**
Blacks Fork Headwaters	1,565	598	52	208	**2,423**
Cottonwood Creek	777	112	9	577	**1,475**
Fort Bridger	400	56	6	263	**725**
Lower Blacks Fork	127	315	47	690	**1,179**
Lower Smiths Fork	92	13	1	71	**177**
Muddy Creek	3,044	878	120	2,248	**6,290**
Smiths Fork	589	80	7	451	**1,127**
Smiths Fork Headwaters	1,079	397	34	181	**1,691**
Lyman	146	36	4	126	**312**
Upper Smiths Fork	470	67	6	351	**894**
Total	**8,434**	**2,572**	**288**	**5,277**	**16,571**

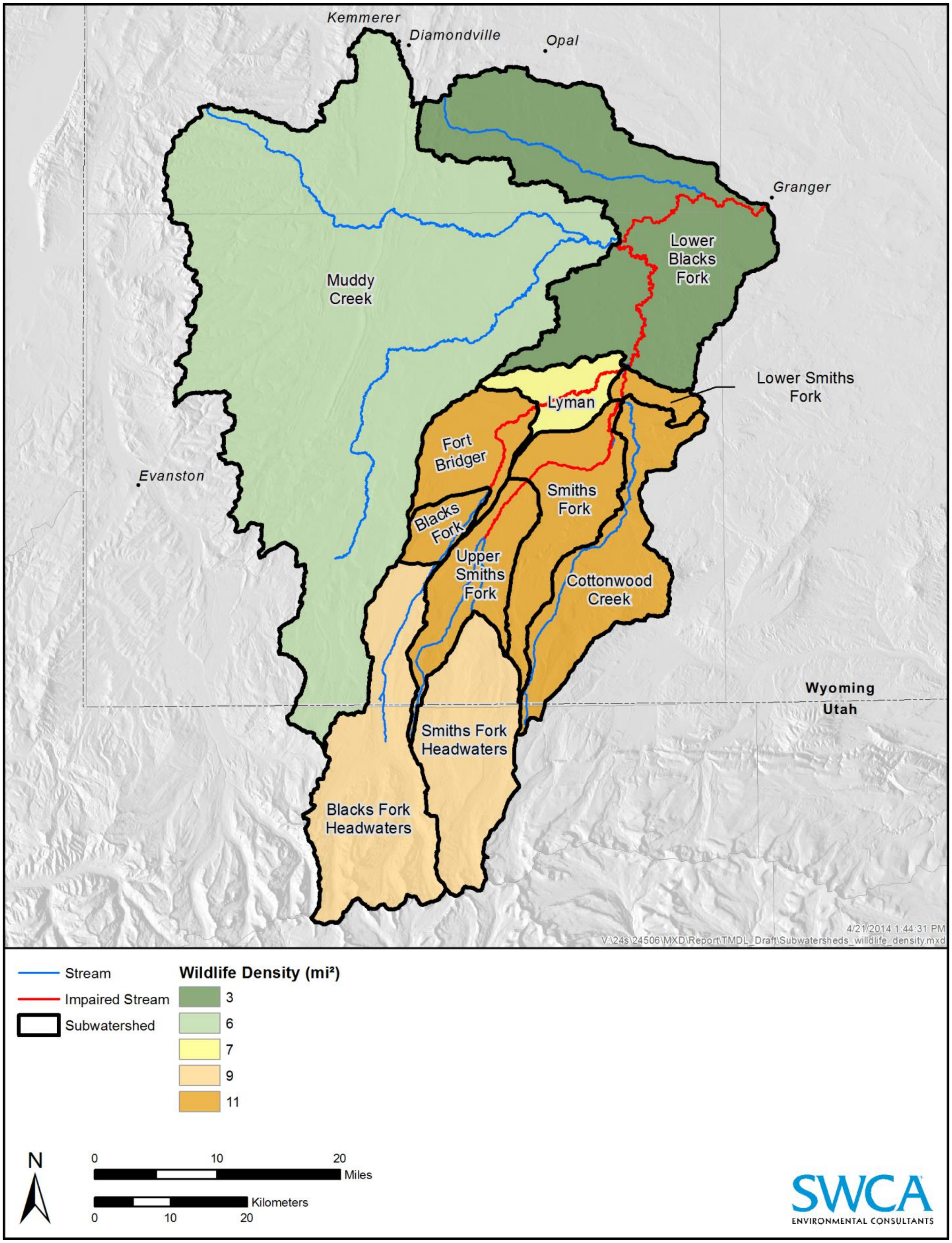

Figure 4.14. Wildlife density expressed as number of animals per square mile for each subwatershed. (*Note*: mi^2 = square miles).

Wildlife seasonality was explored using habitat range maps intersected with subwatershed boundaries to identify months of the year in which wildlife reside in the subwatershed (Figure 4.15). Generally speaking, winter range is from December 1 to May 1; however, variation does occur given weather patterns, forage availability, hunting pressure, human disturbance, and other factors.[2] Furthermore, each species and subpopulation will react differently according to the aforementioned matrix of factors affecting migration. Nonetheless, seasonal herd movements were estimated for the four species, and populations were summed by month (Table 4.14). In general, the inner subwatersheds exhibit higher wildlife populations during the winter months when snow and severe weather push animals to lower elevations. Contrastingly, headwater regions see higher populations during the summer as mostly elk and deer move to higher grounds.

As a result of these seasonal movements, *E. coli* loading from wildlife is most significant in the Blacks Fork Headwaters and Smiths Fork Headwaters subwatersheds across all hydrologic regimes (Table 4.15).

Table 4.14. Total Monthly Wildlife Populations for each Subwatershed for Moose, Elk, Deer, and Antelope

Subwatershed	January	February	March	April	May	June	July	August	September	October	November	December
Blacks Fork	278	278	278	278	111	111	111	111	111	111	111	278
Blacks Fork Headwaters	2,215	2,215	2,215	2,215	2,423	2,423	2,423	2,423	2,423	2,423	2,423	2,215
Cottonwood Creek	1,475	1,475	1,475	1,475	1,466	1,466	1,466	1,466	1,466	1,466	1,466	1,475
Fort Bridger	725	725	725	725	263	263	263	263	263	263	263	725
Lower Blacks Fork	1,179	1,179	1,179	1,179	864	864	864	864	864	864	864	1,179
Lower Smiths Fork	177	177	177	177	71	71	71	71	71	71	71	177
Muddy Creek	6,290	6,290	6,290	6,290	6,290	6,290	6,290	6,290	6,290	6,290	6,290	6,290
Smiths Fork	1,127	1,127	1,127	1,127	451	451	451	451	451	451	451	1,127
Smiths Fork Headwaters	1,691	1,691	1,691	1,691	1,691	1,691	1,691	1,510	1,510	1,510	1,510	1,510
Lyman	312	312	312	312	126	126	126	126	126	126	126	312
Upper Smiths Fork	893	893	893	893	821	821	821	821	821	821	821	893

[2] Personal communication, email between Lucy Parham (SWCA) and Jeff Short (WGFD) regarding wildlife migration, November 5, 2013.

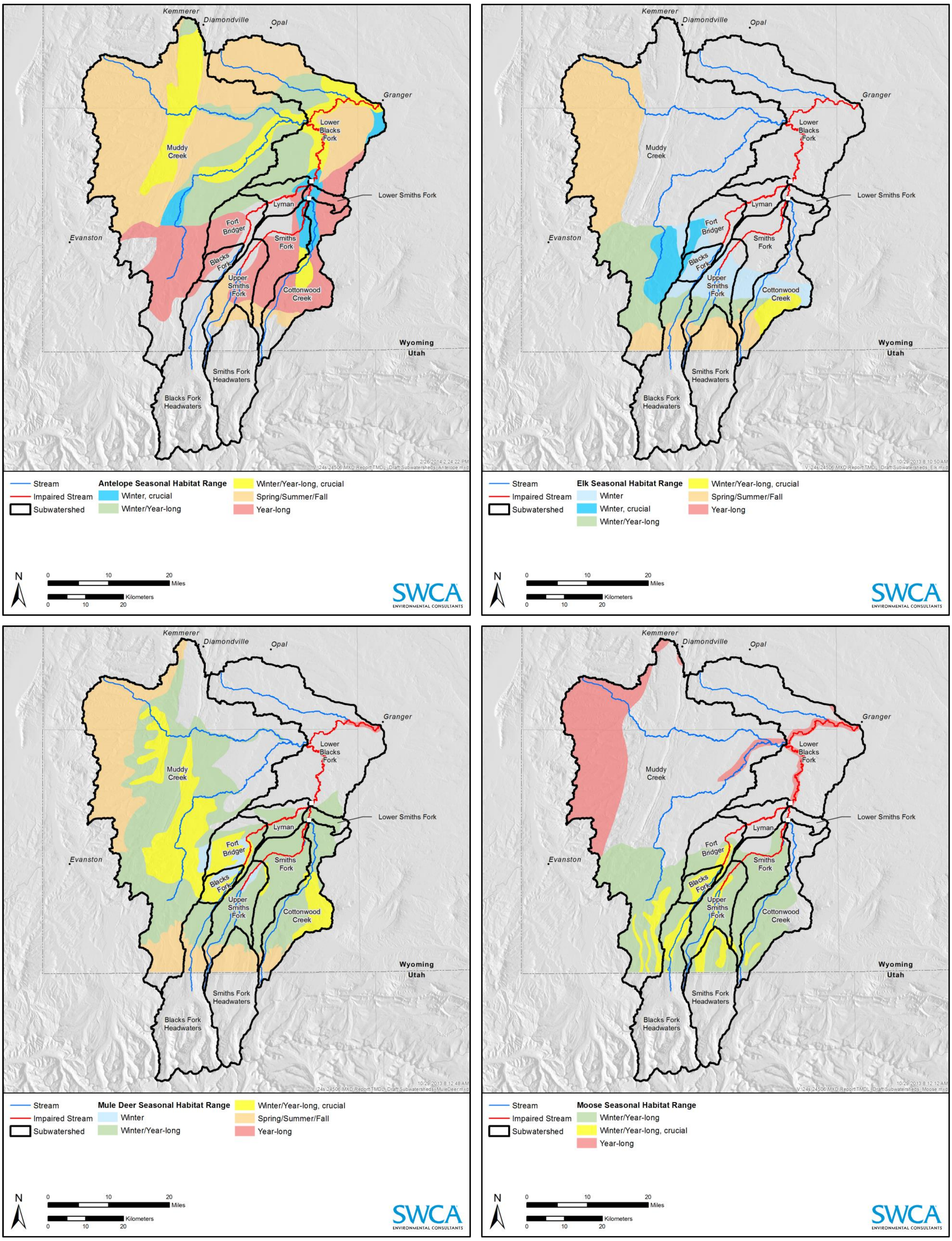

Figure 4.15. Habitat ranges for antelope, elk, mule deer, and moose in each subwatershed.

This page intentionally blank

Table 4.15. Wildlife Loads (G-cfu/season) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed										
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	1,459	221	720	1,009	481	3,786	146	21	2,444	26	309
	Summer	3,263	523	1,826	295	979	629	4,824	4	460	4	111
	Fall	807	89	354	133	151	247	698	1	30	1	27
Dry	Spring	1,077	301	180	193	261	720	368	5	51	2	3,056
	Summer	2,474	456	18	0	695	425	1,003	1	244	1	66
	Fall	450	65	6	29	69	142	143	0	440	0	16
Wet	Spring	4,829	409	182	1,740	2,317	3,432	1,385	53	804	61	2,714
	Summer	4,267	2,778	1,485	2,080	1,756	6,766	146	14	20,655	9	1,432
	Fall	1,259	307	175	571	306	613	1,519	3	402	3	242

4.2.3.3. SEPTIC SYSTEMS

Septic systems have the potential to contribute pathogens to waterways by means of failures, malfunctions, improper design, poor site location, or direct pipe discharge to a stream. Systems that are functioning properly treat wastewater by an underground leach field that removes pathogens by filtering, adsorption, natural die-off, and other biochemical processes. Problems arise when leach fields fail or interact with shallow groundwater, causing wastewater to reach a stream without proper treatment. Identifying septic contribution to pathogen loading requires estimating the number of septic systems in each subwatershed and understanding their position in the landscape, particularly with regard to irrigation practices.

In the Blacks Fork Watershed, only three subwatersheds have sewered municipalities; therefore, all residences outside the municipality were assumed to be unsewered, and septic counts were conducted using aerial imagery overlain with subwatershed boundaries. For the Smiths Fork subwatershed where the town of Mountain View is located, a map was provided of sewer lines, and any parcel with a sewer line connection was assumed to be a part of the service area. Residences on parcels outside the service area were counted as unsewered using aerial imagery. Unsewered estimates for the Lyman and Fort Bridger subwatersheds were generated by identifying town boundaries and then counting those residences outside of the boundaries using aerial imagery. Total septic systems and septic system density by subwatershed are shown in Table 4.16 and Figure 4.16.

Table 4.16. Total Septic Systems and Septic System Density for each Subwatershed

Subwatershed	Total Septics	Density (number/square mile)
Blacks Fork	48	2
Blacks Fork Headwaters	123	1
Cottonwood Creek	4	< 1
Fort Bridger	375	6
Lower Blacks Fork	13	< 1
Lower Smiths Fork	2	< 1
Muddy Creek	56	< 1
Smiths Fork	349	3
Smiths Fork Headwaters	17	< 1
Lyman	335	8
Upper Smiths Fork	232	3

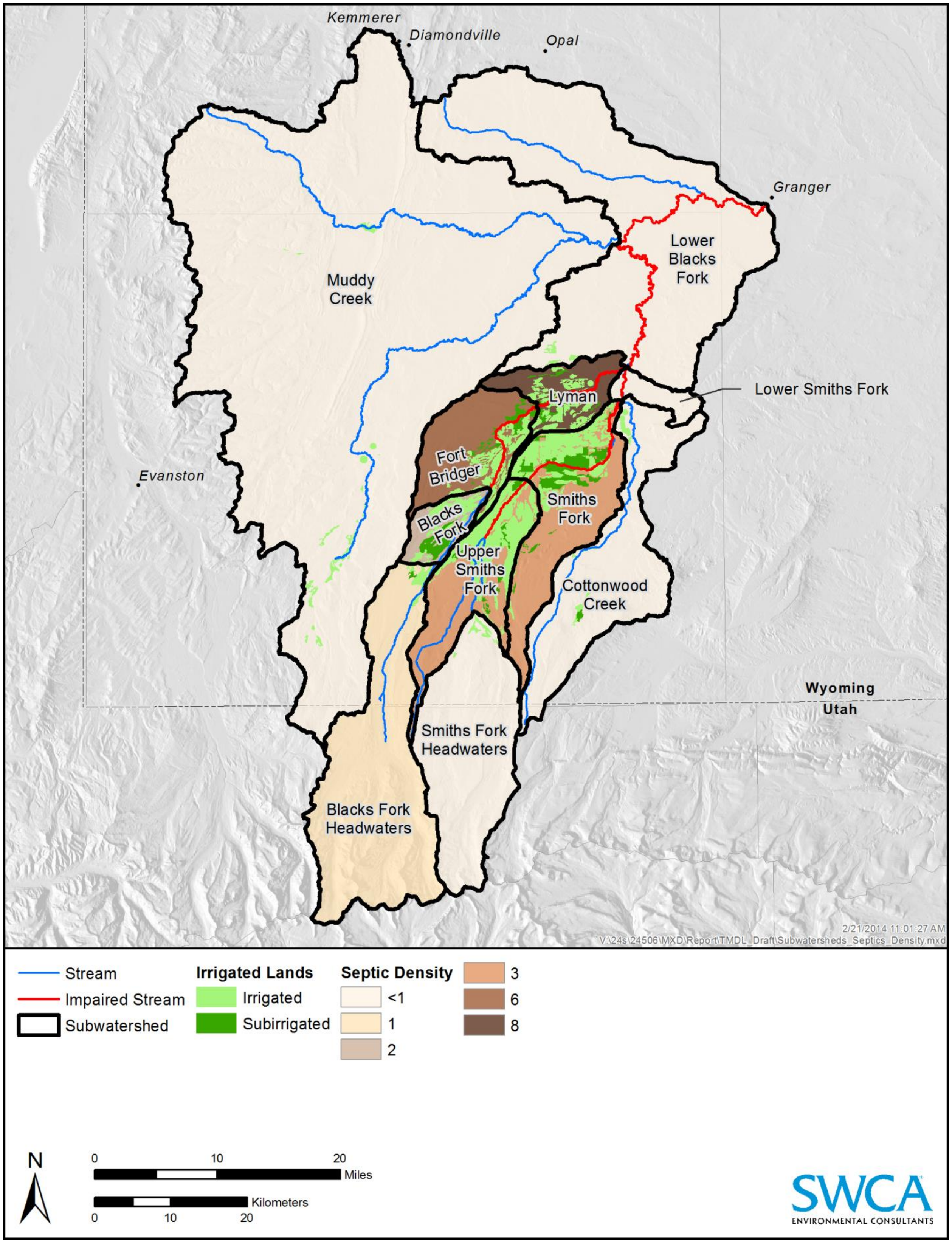

Figure 4.16. Septic system density in the Blacks Fork Watershed.

Three criteria were used to identify septic systems with the greatest potential for pathogen contribution to waterways: 1) underlying aquifer sensitivity, 2) distance to a waterway, and 3) irrigated land. The first criterion, aquifer sensitivity for the region, was provided by the Wyoming Groundwater Vulnerability Mapping Project (WDEQ 1998) and includes geographic information system layers that delineate areas of high aquifer sensitivity based on various factors such as depth to groundwater, soils, aquifer recharge, land surface slope, and vadose zone. The project defines aquifer sensitivity as the relative ease with which a contaminant applied on or near the land surface can migrate to the aquifer of interest. Subwatershed boundaries were intersected with aquifer sensitivity mapping to identify areas of high sensitivity in each subwatershed (Table 4.17).

The second criterion was distance to surface water. Although many septics are in areas of high aquifer sensitivity, the groundwater transport distance is large enough that pathogens would likely die during transit. Therefore, it is important to identify a 'critical' distance between a septic system and a waterway that indicates a greater potential for pathogen contribution. The critical distance employed in this study was assumed to be similar to that used in the Goose Creek pathogen TMDL project (SWCA 2010). The distance identified was 100 meters and was calculated using assumptions about pathogen survival in groundwater and groundwater velocity according to Darcy's law. For each subwatershed, all septics within 100 meters of a National Hydrography Dataset (NHD) stream were identified (see Table 4.17).

The third criterion was irrigation, because it can have a flushing effect on failed septics and can inundate otherwise functioning leach fields (providing the means for transporting *E. coli* before die-off). The analysis involved identifying those septics on either an irrigated or subirrigated landscape. All septics on irrigated or subirrigated land were mapped and categorized by subwatershed (see Table 4.17).

Having recognized those septics that fit one of the aforementioned criteria, those systems that met all three were then identified as "high-priority" systems in that they would be the most likely to contribute pathogens to waterways (see Table 4.17; Figure 4.17). The Fort Bridger, Smiths Fork, Lyman, and Upper Smiths Fork subwatersheds had much higher numbers of priority septics than other subwatersheds. The number and density of septics translate to high *E. coli* load contribution to surface waters particularly during a wet climate condition (Table 4.18). There is also a large number of septics in an irrigated landscape (see Figure 4.17) that can further increase the likelihood of septic contribution through leach field flushing.

Table 4.17. Septic Systems on Irrigated Land and in a High Aquifer Sensitivity Landscape within 100 meters of an National Hydrography Dataset–Identified Stream

Subwatershed	High-Priority Septics	Aquifer Sensitivity	Septics within 100 Meters of an NHD-Identified Stream	Septics on Irrigated Lands
Blacks Fork	10	36	13	16
Blacks Fork Headwaters	9	35	22	3
Cottonwood Creek	0	0	1	0
Fort Bridger	83	301	115	83
Lower Blacks Fork	1	3	5	0
Lower Smiths Fork	0	0	0	0
Muddy Creek	1	1	24	5
Smiths Fork	74	313	86	147
Smiths Fork Headwaters	3	3	10	0
Lyman	69	180	121	80
Upper Smiths Fork	120	215	130	158

Table 4.18. Loads (G-cfu/season) from Septic Systems for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		**Subwatershed**										
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	Spring	17	43	287	697	1	1,536	56	0	-	0	1
	Summer	37	101	729	204	2	255	1,853	0	-	0	0
	Fall	9	17	141	92	0	100	268	0	-	0	0
Dry	Spring	12	58	72	133	1	292	141	0	-	0	6
	Summer	28	88	7	0	2	172	385	0	-	0	0
	Fall	5	13	2	20	0	58	55	0	-	0	0
Wet	Spring	56	79	73	1,201	5	1,393	532	0	-	0	5
	Summer	49	538	592	1,436	4	2,746	56	0	-	0	3
	Fall	14	60	70	394	1	249	583	0	-	0	0

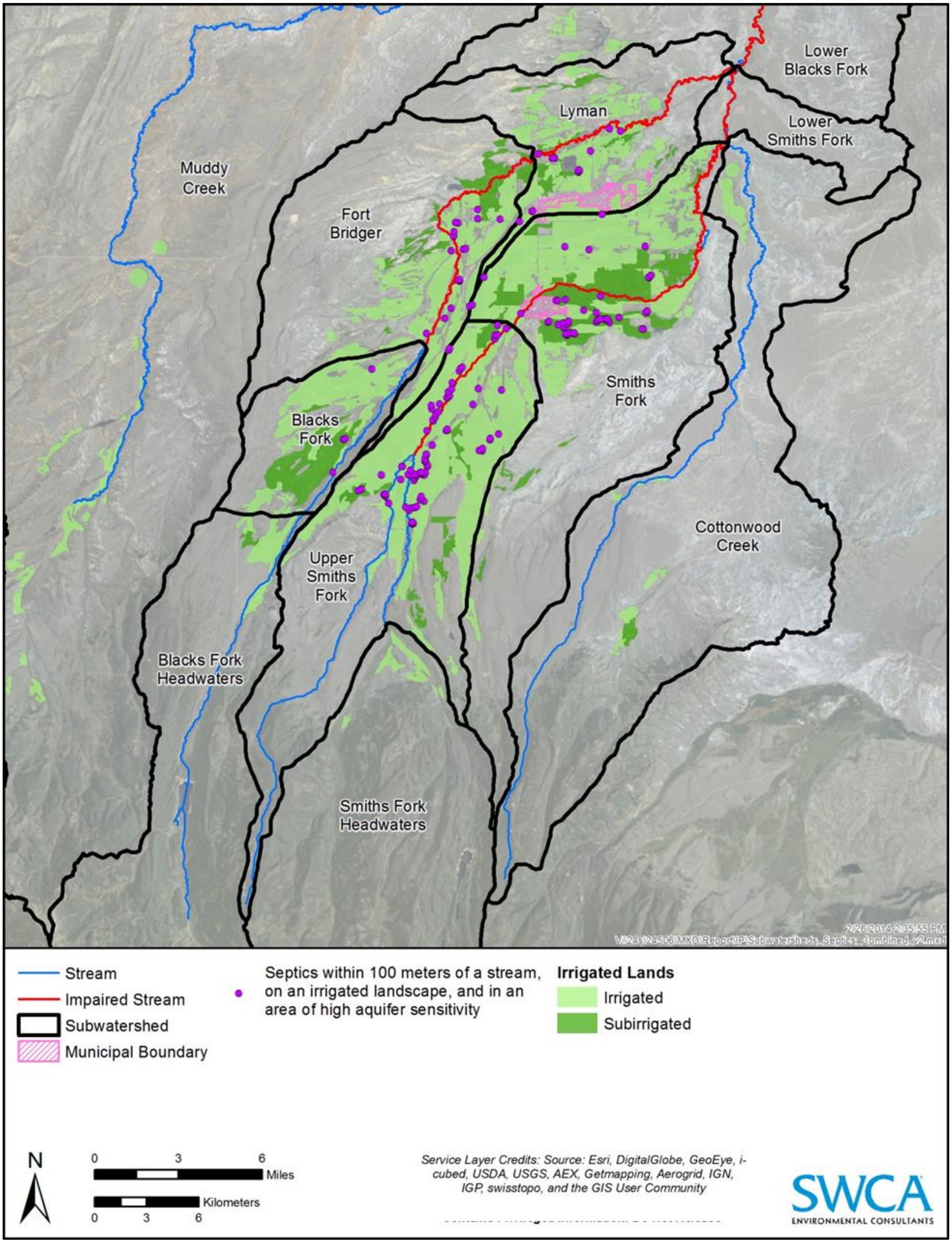

Figure 4.17. Location of high-priority septics in the Blacks Fork Watershed.

4.2.3.4. PET WASTE

Pet waste contribution to *E. coli* loading occurs from stormwater runoff from residential lawns, dog parks, and other typically urban landscapes where impervious surfaces are prevalent. Due to the rural nature of the Blacks Fork Watershed, pet waste contribution is small compared to other sources, even in the more populated subwatersheds of Fort Bridger, Lyman, and Smiths Fork (Table 4.19). However, as these rural communities become more developed, pet waste could increasingly become a significant source. As such, it is important to consider the current magnitude and origin of *E. coli* from pet waste and include it as a source to be reduced.

Table 4.19. Pet Waste Loads (G-cfu/season) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Subwatershed										
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	4	6	77	346	0	147	17	0	4	0	0
	Summer	8	14	195	100	1	24	548	0	1	0	0
	Fall	2	2	38	46	0	10	79	0	0	0	0
Dry	Spring	3	8	19	66	0	28	42	0	0	0	1
	Summer	6	12	2	0	0	16	114	0	0	0	0
	Fall	1	2	1	9	0	5	16	0	1	0	0
Wet	Spring	12	11	19	597	1	133	157	0	1	0	1
	Summer	11	74	158	714	1	262	17	0	36	0	1
	Fall	3	8	19	196	0	24	173	0	1	0	0

4.3. Source Load Summary

E. coli loads by both point source and nonpoint source are presented below for each subwatershed during the three seasons of a normal (Tables 4.20–4.22), dry (Tables 4.23–4.25), and wet (Tables 4.26–4.28) climate condition. Livestock continue to be a dominant source in several subwatersheds, as does irrigation in Lyman and Smiths Fork subwatersheds. The impairment in Lower Smiths Fork is largely a result of upstream loads particularly during a normal climate condition. Wildlife contribution occurs primarily in the headwaters subwatersheds and Cottonwood Creek. The largest current loads occur in Smiths Fork and Lyman subwatersheds (Figure 4.18).

Table 4.20. Summary of *E. coli* Loads (G-cfu/season) during a Normal-Spring Hydrologic Regime (May–June)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	803	–	43	6	221	6,114	7,186	–	**7,186**
Blacks Fork Headwaters	0	–	17	4	1,459	303	1,783	–	**1,783**
Cottonwood Creek	0	–	0	0	21	59	80	–	**80**
Fort Bridger	1,106	–	287	77	719	10,249	12,439	36	**12,475**
Lower Blacks Fork	1,095	–	1	0	309	966	2,371	–	**2,371**
Lower Smiths Fork	27,887	–	0	4	2,444	11,971	42,306	–	**42,306**
Muddy Creek	0	–	0	0	26	162	188	–	**188**
Smiths Fork	23,823	1,290	56	17	146	2,541	27,873	15	**27,888**
Smiths Fork Headwaters	0	–	1	0	481	123	605	–	**605**
Lyman	9,805	1,266	697	346	1,009	16,770	29,892	90	**29,982**
Upper Smiths Fork	0	0	1,536	147	3,786	66,828	72,297	–	**72,297**

Table 4.21. Summary of *E. coli* Loads (G-cfu/season) during a Normal-Summer Hydrologic Regime (July–August)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	2,683	–	101	14	523	14,480	17,801	–	**17,801**
Blacks Fork Headwaters	0	–	37	8	3,263	3,302	6,611	–	**6,611**
Cottonwood Creek	0	–	0	0	4	12	16	–	**16**
Fort Bridger	0	–	728	195	1,826	13,079	15,828	14	**15,842**
Lower Blacks Fork	183	–	0	0	111	141	436	–	**436**
Lower Smiths Fork	42,175	–	0	1	460	1,114	43,750	–	**43,750**
Muddy Creek	0	–	0	0	4	14	18	–	**18**
Smiths Fork	5,390	15,307	1,853	548	4,824	72,331	100,253	101	**100,354**
Smiths Fork Headwaters	0	–	2	1	979	742	1,724	–	**1,724**
Lyman	10,429	3,806	204	101	295	1,750	16,585	95	**16,680**
Upper Smiths Fork	0	–	255	24	629	6,543	7,451	–-	**7,451**

Table 4.22. Summary of *E. coli* Loads (G-cfu/season) during a Normal-Fall Hydrologic Regime (September)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	317	–	17	2	89	2,477	2,903	–	**2,903**
Blacks Fork Headwaters	0	–	9	2	807	136	955	–	**955**
Cottonwood Creek	0	–	0	0	1	3	4	–	**4**
Fort Bridger	480	–	141	38	354	2,632	3,646	6	**3,651**
Lower Blacks Fork	28	–	0	0	27	40	96	–	**96**
Lower Smiths Fork	6,540	–	–	0	30	71	6,641	–	**6,641**
Muddy Creek	0	–	0	0	1	2	3	–	**3**
Smiths Fork	2,279	2,599	268	79	698	10,641	16,565	7	**16,573**
Smiths Fork Headwaters	0	–	0	0	151	122	273	–	**273**
Lyman	1,161	334	92	46	133	801	2,567	60	**2,627**
Upper Smiths Fork	0	–	100	10	247	2,652	3,008	–	**3,008**

Table 4.23. Summary of E. coli Loads (G-cfu/season) during a Dry-Spring Hydrologic Regime (May–June)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	511	–	58	8	301	8,331	9,209	–	**9,209**
Blacks Fork Headwaters	0	–	12	3	1,077	224	1,316	–	**1,316**
Cottonwood Creek	0	–	0	0	5	13	18	–	**18**
Fort Bridger	1,267	–	72	19	180	2,562	4,100	11	**4,111**
Lower Blacks Fork	3,121	–	6	1	3,056	9,549	15,733	–	**15,733**
Lower Smiths Fork	13,147	–	0	0	51	248	13,446	–	**13,446**
Muddy Creek	0	–	0	0	2	14	16	–	**16**
Smiths Fork	9,114	2,047	141	42	368	6,381	18,093	26	**18,119**
Smiths Fork Headwaters	0	–	1	0	261	67	328	–	**328**
Lyman	3,094	445	133	66	193	3,202	7,133	139	**7,272**
Upper Smiths Fork	0	–	292	28	720	12,703	13,743	–	**13,743**

Table 4.24. Summary of *E. coli* Loads (G-cfu/season) during a Dry-Summer Hydrologic Regime (July–August)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	1,734	–	88	12	456	12,631	14,921	–	**14,921**
Blacks Fork Headwaters	0	–	28	6	2,474	2,503	5,011	–	**5,011**
Cottonwood Creek	0	–	0	0	1	2	3	–	**3**
Fort Bridger	1,478	–	7	2	18	130	1,635	8	**1,643**
Lower Blacks Fork	91	–	0	0	66	83	240	–	**240**
Lower Smiths Fork	20,879	–	-	0	244	591	21,714	–	**21,714**
Muddy Creek	0	–	0	0	1	3	4	–	**4**
Smiths Fork	3,347	7,494	385	114	1,003	15,035	27,379	5	**27,384**
Smiths Fork Headwaters	0	–	2	0	695	526	1,223	–	**1,223**
Lyman	909	3,708	0	0	0	0	4,617	206	**4,834**
Upper Smiths Fork	0	–	172	16	425	4,420	5,033	–	**5,033**

Table 4.25. Summary of *E. coli* Loads (G-cfu/season) during a Dry-Fall Hydrologic Regime (September)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	132	–	13	2	65	1,802	2,014	–	**2,014**
Blacks Fork Headwaters	0	–	5	1	450	76	532	–	**532**
Cottonwood Creek	0	–	0	0	0	1	1	–	**1**
Fort Bridger	383	–	2	1	6	42	434	2	**436**
Lower Blacks Fork	40	–	0	0	16	23	79	–	**79**
Lower Smiths Fork	5,688	–	–	1	440	1,062	7,191	–	**7,191**
Muddy Creek	0	–	0	0	0	2	2	–	**2**
Smiths Fork	1,388	1,826	55	16	143	2,176	5,605	84	**5,689**
Smiths Fork Headwaters	0	–	0	0	69	56	125	–	**125**
Lyman	202	735	20	10	29	177	1,174	63	**1,236**
Upper Smiths Fork	0	–	58	5	142	1,526	1,731	–	**1,731**

Table 4.26. Summary of *E. coli* Loads (G-cfu/season) during a Wet-Spring Hydrologic Regime (May–June)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	3,047	–	79	11	409	11,342	14,888	–	**14,888**
Blacks Fork Headwaters	0	–	56	12	4,829	1,004	5,901	–	**5,901**
Cottonwood Creek	0	–	0	0	53	147	200	–	**200**
Fort Bridger	11,374	–	73	19	183	2,603	14,251	20	**14,271**
Lower Blacks Fork	1,977	–	5	1	2,714	8,480	13,177	–	**13,177**
Lower Smiths Fork	71,381	–	0	1	804	3,940	76,126	–	**76,126**
Muddy Creek	0	–	0	0	61	371	432	–	**432**
Smiths Fork	51,934	1,532	532	157	1,385	24,032	79,572	1,579	**81,151**
Smiths Fork Headwaters	0	–	5	1	2,317	593	2,916	–	**2,916**
Lyman	12,090	540	1,201	597	1,740	28,918	45,086	156	**45,242**
Upper Smiths Fork	52	–	1,393	133	3,432	60,586	65,596	–	**65,596**

Table 4.27. Summary of *E. coli* Loads (G-cfu/season) during a Wet-Summer Hydrologic Regime (July–August)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	4,382	–	538	74	2,778	76,956	84,728	–	**84,728**
Blacks Fork Headwaters	0	–	49	11	4,267	4,318	8,645	–	**8,645**
Cottonwood Creek	0	–	0	0	14	36	50	–	**50**
Fort Bridger	37,380	–	593	158	1,485	10,635	50,252	4	**50,256**
Lower Blacks Fork	456	–	3	1	1,432	1,822	3,714	–	**3,714**
Lower Smiths Fork	38,485	–	0	36	20,655	49,976	109,152	–	**109,152**
Muddy Creek	0	–	0	0	9	32	41	–	**41**
Smiths Fork	29,147	6,915	56	17	146	2,193	38,474	11	**38,485**
Smiths Fork Headwaters	0	–	4	1	1,756	1,331	3,092	–	**3,092**
Lyman	30,977	3,135	1,436	714	2,080	12,329	50,670	8	**50,678**
Upper Smiths Fork	0	–	2,746	262	6,766	70,395	80,169	–	**80,169**

Table 4.28. Summary of *E. coli* Loads (G-cfu/season) during a Wet-Fall Hydrologic Regime (September)

Subwatershed	Upstream	Diverted	Septic	Pet Waste	Wildlife	Livestock	Total Nonpoint Source	Point Source	Total
Blacks Fork	642	–	60	8	307	8,517	9,534	–	**9,534**
Blacks Fork Headwaters	0	–	14	3	1,259	213	1,489	–	**1,489**
Cottonwood Creek	0	–	0	0	3	7	10	–	**10**
Fort Bridger	5,099	–	70	19	175	1,299	6,661	4	**6,665**
Lower Blacks Fork	93	–	0	0	242	357	692	–	**692**
Lower Smiths Fork	29,111	–	0	1	402	970	30,484	–	**30,484**
Muddy Creek	0	–	0	0	3	10	13	–	**13**
Smiths Fork	5,557	2,505	583	173	1,519	23,142	33,479	513	**33,992**
Smiths Fork Headwaters	0	–	1	0	306	247	554	–	**554**
Lyman	5,098	878	394	196	571	3,436	10,573	52	**10,625**
Upper Smiths Fork	0	–	249	24	613	6,588	7,474	–	**7,474**

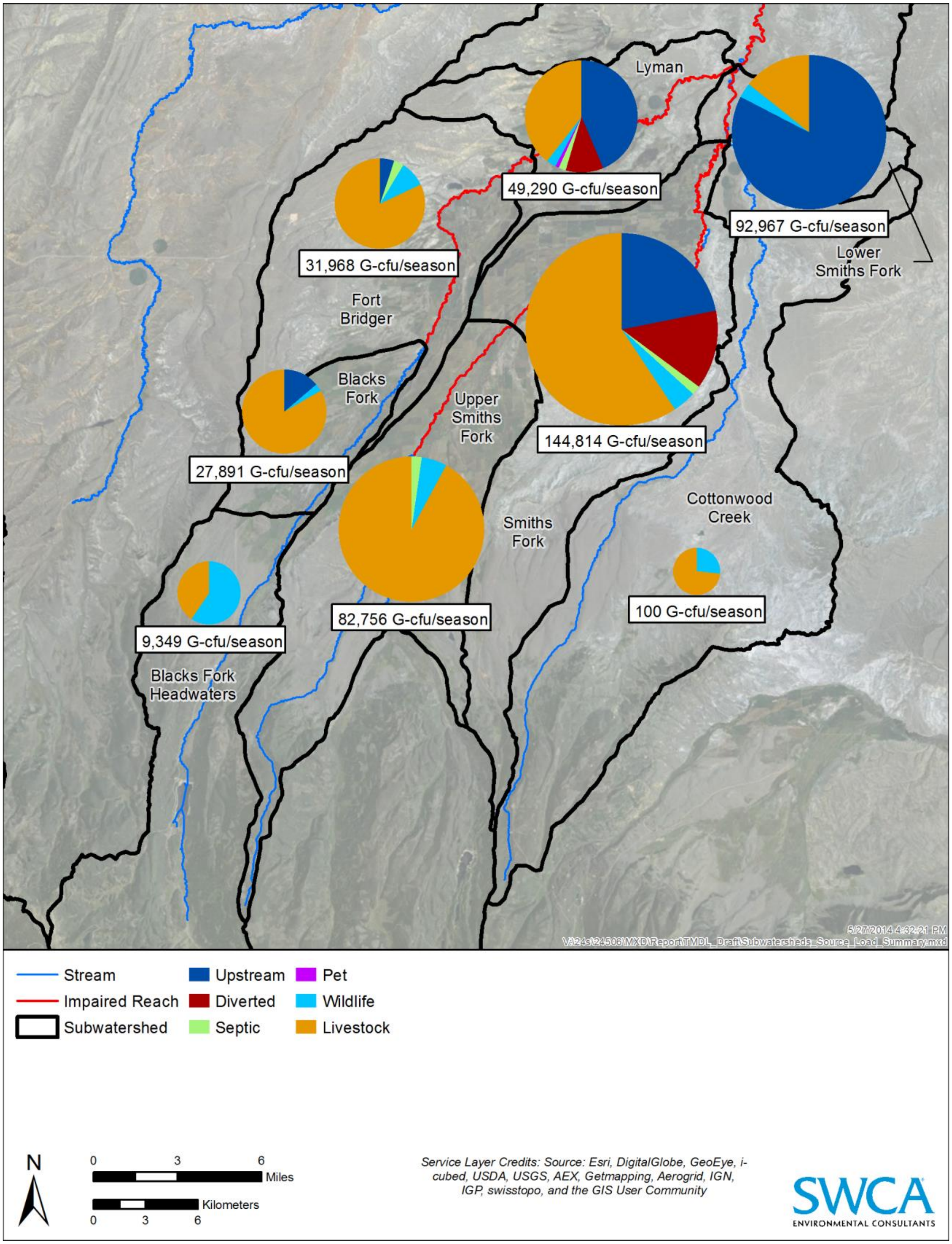

Figure 4.18. Nonpoint source loads for each subwatershed during the impairment season of a normal climate condition.

5. TOTAL MAXIMUM DAILY LOADS SUMMARY

5.1. Water Quality Targets and Linkage

The water quality target for the summer recreation season (May 1–September 30) is 126 organisms per 100 mL, measured as a geomean within a 60-day time span. This water quality target is derived directly from the water quality standards for bacteria established by the State of Wyoming (Table 5.1). *E. coli* is the bacteria parameter with a numeric water quality standard for Wyoming waters. In 1986, the EPA recommended that *E. coli* replace fecal coliform bacteria in state water quality standards (EPA 1986). This recommendation is reflected in current Wyoming water quality standards and in the water quality targets identified for this TMDL. The water quality targets used for this TMDL are sufficient to protect the single-sample maximum concentration standards identified during the summer recreation season.

Table 5.1. Wyoming Numeric Surface Water Quality Standard for *E. coli* Bacteria

Parameter	Water Quality Standard Reference	Standard/Description
E. coli bacteria*	Section 27	a) Standard during the summer recreation season (May 1–September 30): concentrations of *E. coli* bacteria shall not exceed a geomean of 126 organisms per 100 mL during any consecutive 60-day period. b) Standard during the winter recreation season (October 1–April 30): concentrations of *E. coli* bacteria shall not exceed a geomean of 630 organisms per 100 mL during any consecutive 60-day period.

Source: WDEQ (2013a).

* Original impairments were based on the old fecal coliform standard: geomean of five samples obtained during separate 24-hour periods within a 30-day time span shall not exceed 200 organisms per 100 mL. The Wyoming standard was changed from fecal coliform to *E. coli* in 2007.

5.2. Total Maximum Daily Loads Analysis

5.2.1. Current Loads Summary for the Summer Season (May–September)

To calculate current *E. coli* loads, a geomean was first generated for the nine hydrologic regimes within each subwatershed. All available *E. coli* concentration data from the representative water quality site for each hydrologic regime were used (Table 5.2). In the case of Cottonwood Creek where little data were available, all available samples were used to calculate a geomean that was applied to all hydrologic regimes. This same geomean was applied to Muddy Creek where no data were available. A similar approach was used for Lower Blacks Fork where samples from other hydrologic regimes were averaged to fill gaps in hydrologic regimes where no data were available. In cases where *E. coli* concentrations were zero, the value was changed to one because geomeans cannot be calculated using zero values. Geomean values were categorized by season and climate to further delineate temporal and spatial data related to impairments (Figure 5.1).

Table 5.2. Seasonal Geomean (cfu/100 mL) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	Spring	2.36	18.61	61.12	123.94	2.36	430.30	120.23	1.43	147.03	1.43	2.00
	Summer	16.45	94.88	364.70	203.16	16.45	178.09	891.25	1.43	352.82	1.43	2.00
	Fall	10.57	80.68	333.87	119.83	10.57	249.11	561.57	1.43	207.01	1.43	1.76
Dry	Spring	2.42	38.61	95.36	132.34	2.42	336.91	226.12	1.43	145.27	1.43	60.00
	Summer	21.22	150.91	191.57	93.91	21.22	404.47	434.20	1.43	332.68	1.43	4.82
	Fall	10.04	116.80	188.51	95.27	10.04	376.18	338.73	1.43	419.05	1.43	4.82
Wet	Spring	5.94	15.46	29.16	85.10	5.94	172.96	165.16	1.43	124.40	1.43	4.82
	Summer	12.67	120.78	282.73	233.15	12.67	459.78	157.75	1.43	356.55	1.43	4.82
	Fall	11.32	71.66	212.29	209.47	11.32	248.86	694.93	1.43	436.04	1.43	4.82

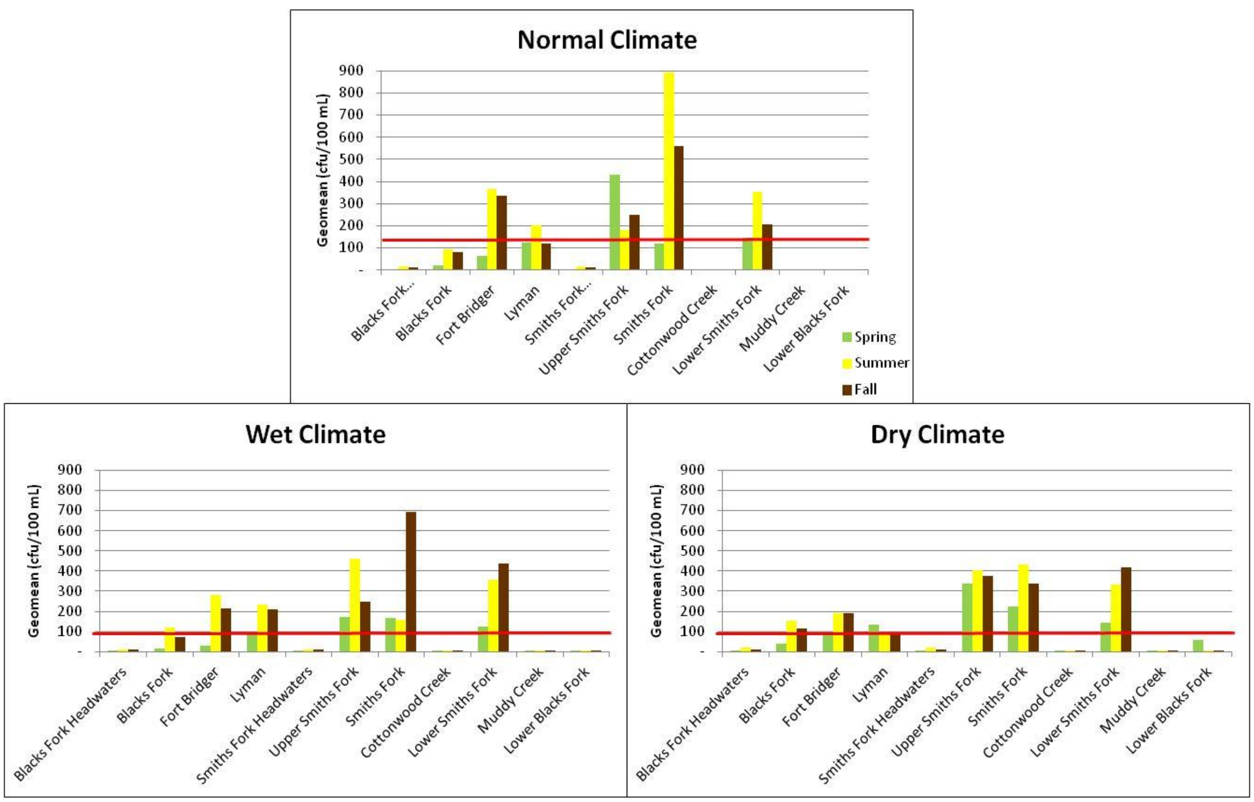

Figure 5.1. Seasonal geomeans for each subwatershed during spring, summer, and fall of a normal, wet, and dry climate condition. The red line denotes the Wyoming Department of Environmental Quality *E. coli* standard (126 cfu/mL).

Flows used to calculate *E. coli* loads were taken from the Blacks Fork Basin model (see section 3.5.4.1 for model description). The net flow for each month of the impairment season (May–September) for the three different climate conditions (normal, dry, and wet) was used at nodes that represent each of the 11 subwatersheds (see Figure 1.2; Table 5.3). The monthly net flow model value is the difference between total inflow (which accounts for irrigation returns) and total outflow (which accounts for irrigation diversions). Monthly net flows were compiled and formatted in a similar manner to geomeans so that loads could be easily calculated (Table 5.4).

Table 5.3. Subwatersheds in the Blacks Fork Watershed used in TMDL Development and their Associated Blacks Fork Basin Model Node and UCCD Water Quality Monitoring Site

Subwatershed	Model Node	Water Quality Site	Impairment
Muddy Creek	10.02	CC1	Not listed as impaired
Lower Blacks Fork	13.01	BF1	Fecal coliform
Lyman	1.26	BF3	*E. coli*
Fort Bridger	1.24	BF5	*E. coli*
Blacks Fork	1.16	BF8	Not listed as impaired
Blacks Fork Headwaters	1.08	BF10	Not listed as impaired
Lower Smiths Fork	6.02	SF1	Habitat and *E. coli*
Cottonwood Creek	5.04	CC1	Not listed as impaired
Smiths Fork	4.10	SF2	Fecal coliform
Upper Smiths Fork	4.08	SF4	Fecal coliform
Smiths Fork Headwaters	4.01	BF10	Not listed as impaired

Table 5.4. Seasonal Modeled Flows (acre-feet/month) for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	61,253	31,299	16,547	19,612	20,794	13,622	18,804	4,522	23,326	10,654	96,099
	Summer	32,572	15,211	3,521	6,656	8,493	3,392	9,129	924	10,053	1,045	17,668
	Fall	7,325	2,918	887	1,777	2,097	979	2,392	208	2,601	164	4,430
Dry	Spring	44,088	19,339	3,495	4,454	11,003	3,307	6,497	1,007	7,504	902	21,257
	Summer	19,148	8,016	695	3,387	4,672	1,009	5,113	179	5,292	220	4,031
	Fall	4,299	1,397	187	1,052	1,010	373	1,361	30	1,391	90	1,320
Wet	Spring	80,578	78,064	39,677	43,099	39,834	30,747	39,834	11,306	49,611	24,500	221,613
	Summer	55,296	56,872	14,411	17,622	19,778	14,136	19,778	2,832	24,818	2,320	62,454
	Fall	10,662	10,787	2,545	4,112	3,966	2,434	3,965	560	5,668	763	11,647

The current *E. coli* load for each of the 11 subwatersheds was generated by sorting data into representative data sets by assigning a hydrologic regime that consists of a combination of an irrigation season based on the month and a hydrologic condition based on the year in which the data were collected (see Table 3.9). Geomeans were multiplied by the corresponding modeled flow (Table 5.3) to generate a monthly current load:

Load [giga-cfu/month] = flow rate [liters/month] × geomean [cfu/100 mL] × 10^{-8} (conversion factor to giga-cfus/month)

Monthly loads were summed by season to obtain current seasonal loads. Current loads for each of the 11 subwatersheds are presented in Table 5.5 and expressed as seasonal values for each climate condition. Seasonal loads (spring, summer, fall) are considered the most appropriate averaging period for this TMDL given the recently revised Wyoming state standard that evaluates geomeans across a 60-day time period. The largest current loads generally occur in the spring season in the upper and lower reaches of the watershed and in the summer season in the middle reaches of the watershed (e.g., Fort Bridger, Lyman, and Smiths Fork) (Figure 5.2). The highest loads in the upper reaches of the watershed generally reflect large flows rather than large *E. coli* concentrations; whereas the high loads in the middle reaches reflect high *E. coli* concentrations.

Seasonal standard water quality loads were calculated in a similar manner to current load. The *E. coli* concentration identified as the state standard (126 cfu/100 mL) was used in place of geomeans and multiplied by the same corresponding model flow used to calculate current load for each hydrologic regime:

Seasonal standard water quality load [giga-cfu/month] = flow rate [liters/month] × 126 [cfu/100 mL] × 10^{-8} (conversion factor to giga-cfus/month)

As with current loads, a seasonal standard water quality load for each season was calculated, and the results were summed to obtain a load for the entire impairment season for each subwatershed (Table 5.6).

Table 5.5. Current Loads (G-cfu) Calculated for each Subwatershed for each Season during the Nine Hydrologic Regimes

Hydrologic Regime		Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	Spring	1,783	7,186	12,474	29,982	605	72,297	27,887	80	42,306	188	2,371
	Summer	6,611	17,802	15,842	16,680	1,724	7,451	100,354	16	43,750	18	436
	Fall	955	2,904	3,652	2,627	273	3,008	16,573	4	6,641	3	96
	Total seasonal load (normal)	*9,348*	*27,892*	*31,970*	*49,288*	*2,601*	*82,756*	*144,815*	*100*	*92,697*	*210*	*2,903*
Dry	Spring	1,316	9,209	4,111	7,271	328	13,743	18,119	18	13,446	16	15,732
	Summer	5,012	14,921	1,643	3,924	1,223	5,034	27,384	3	21,715	4	240
	Fall	532	2,013	436	1,236	125	1,731	5,688	1	7,191	2	78
	Total seasonal load (dry)	*6,861*	*26,143*	*6,190*	*12,431*	*1,677*	*20,508*	*51,192*	*23*	*42,350*	*21*	*16,049*
Wet	Spring	5,901	14,887	14,271	45,242	2,917	65,595	81,152	200	76,127	432	13,178
	Summer	8,644	84,728	50,257	50,678	3,092	80,169	38,485	50	109,152	41	3,714
	Fall	1,489	9,534	6,665	10,625	554	7,473	33,991	10	30,484	13	693
	Total seasonal load (wet)	*16,034*	*109,149*	*71,194*	*106,545*	*6,563*	*153,238*	*153,627*	*259*	*215,763*	*486*	*17,585*

Note: Total seasonal load represents the total impairment load (May–September).

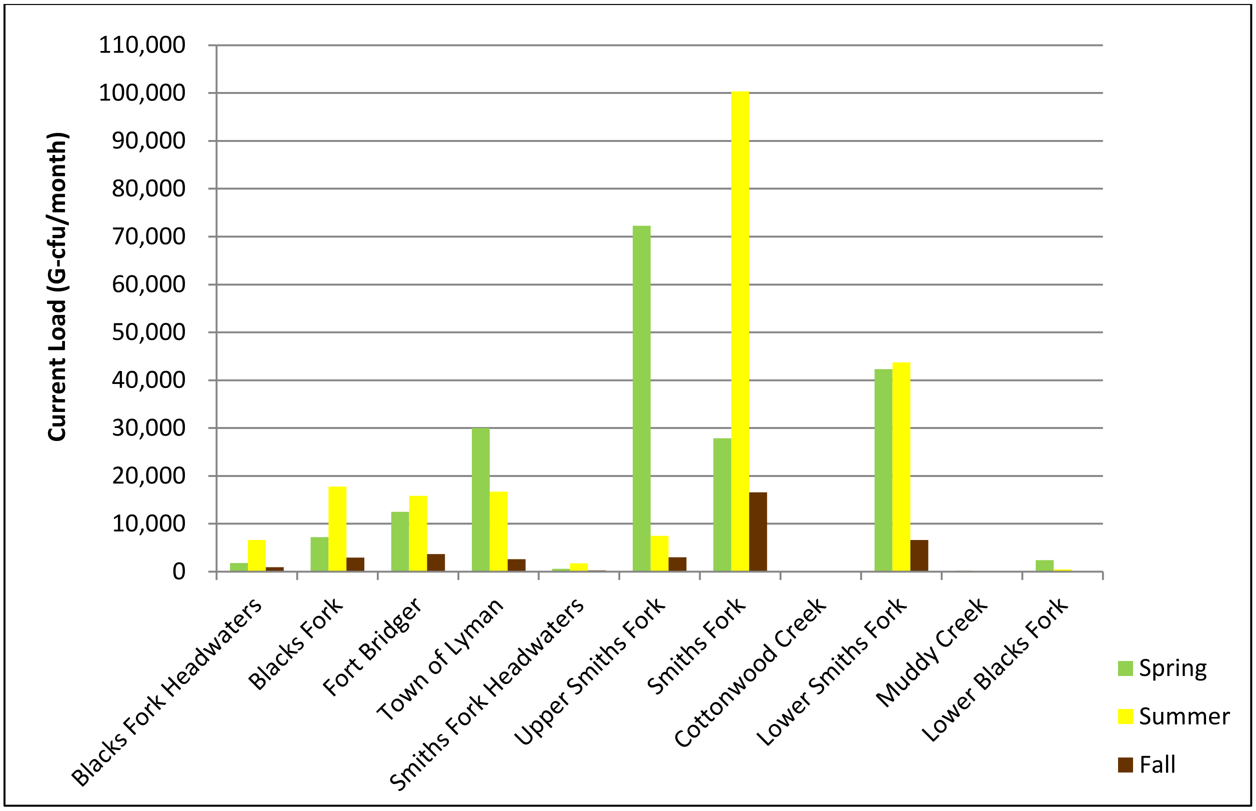

Figure 5.2. Seasonal *E. coli* loads calculated for each subwatershed during normal climate conditions.

Table 5.6. Subwatershed Standard Water Quality Loads (G-cfu) Calculated for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		**Impaired Reach 1**				**Impaired Reach 4**			**Impaired Reach 3**		**Impaired Reach 2**	
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	Spring	95,198	48,644	25,716	30,481	32,318	21,170	29,225	7,029	36,254	16,559	149,355
	Summer	50,623	23,641	5,473	10,345	13,200	5,272	14,187	1,437	15,624	1,625	27,460
	Fall	11,384	4,535	1,378	2,762	3,259	1,522	3,718	323	4,042	254	6,885
	Total standard water quality load (normal)	*157,205*	*76,819*	*32,567*	*43,588*	*48,777*	*27,964*	*47,131*	*8,788*	*55,920*	*18,438*	*183,701*
Dry	Spring	68,520	30,057	5,432	6,923	17,101	5,140	10,097	1,565	11,662	1,401	33,038
	Summer	29,759	12,458	1,081	5,265	7,260	1,568	7,947	278	8,224	342	6,266
	Fall	6,681	2,172	291	1,634	1,570	580	2,116	46	2,162	140	2,051
	Total standard water quality load (dry)	*104,959*	*44,687*	*6,804*	*13,821*	*25,931*	*7,287*	*20,159*	*1,889*	*22,049*	*1,883*	*41,355*

Table 5.6. Subwatershed Standard Water Quality Loads (G-cfu) Calculated for each Subwatershed during the Nine Hydrologic Regimes

Hydrologic Regime		Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
Climate	**Season**	**Blacks Fork Headwaters**	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Wet	Spring	125,234	121,325	61,666	66,983	61,910	47,786	61,910	17,571	77,104	38,078	344,428
	Summer	85,939	88,391	22,397	27,388	30,738	21,970	30,739	4,403	38,572	3,606	97,066
	Fall	16,571	16,765	3,956	6,391	6,164	3,783	6,163	871	8,809	1,185	18,101
	Total standard water quality load (wet)	*227,744*	*226,481*	*88,019*	*100,762*	*98,812*	*73,539*	*98,812*	*22,845*	*124,487*	*42,870*	*459,595*

Note: Standard water quality load represents flow multiplied by the Wyoming *E. coli* standard (126 cfu/100mL).

5.2.1.1. TOTAL MAXIMUM DAILY LOADS

TMDLs were calculated using current and standard water quality loads. The percentage reduction in current load required to meet the standard water quality load is presented in Table 5.7 for each subwatershed during the nine hydrologic regimes. Percentage reduction was calculated using the following equation:

$$\text{Load Reduction (\%)} = \frac{\text{current load - standard water quality load}}{\text{current load}} \times 100$$

The highest occurring percentage reduction in each of the four impaired reaches was identified and applied to all seasons and corresponding subwatersheds (Table 5.7). Applying the highest percentage reduction across all subwatersheds and hydrologic regimes for each impaired reach serves several purposes. It ensures that total load reductions during the entire impairment season under varying hydrologic conditions are protective, and it provides simplicity in determining appropriate TMDLs such that a separate TMDL analysis does not have to be conducted for every subwatershed during every hydrologic regime. Furthermore, it incorporates equity among the various subwatersheds such that one specific area is not responsible for achieving stated reductions.

Dispersing the responsibility of *E. coli* reductions among various stakeholders is important when considering the magnitude of upstream contributions to the impaired subwatersheds. For example, during a wet-summer hydrologic regime, the Blacks Fork subwatershed contributes 37,380 G-cfu/season to the Fort Bridger subwatershed as an upstream source (see Table 4.26). This accounts for approximately 75% of the total load in the Fort Bridger subwatershed. Despite the Blacks Fork subwatershed not being listed as impaired, it still contributes a substantial portion of the load to a downstream impaired reach (Fort Bridger), and therefore reductions to Blacks Fork are necessary to achieve sufficient load reductions in Fort Bridger. Excluding upstream watersheds that are not impaired (such as Blacks Fork) would result in an increase in percentage reduction for those subwatersheds that are impaired and in cases where the upstream load is significant, achieving the stated reduction would not be possible. Although this approach is conservative in terms of required percentage reductions, it presents the simplest and most equitable solution that ensures the TMDL is protective.

No percentage reduction was required in Smiths Fork Headwaters subwatershed because it is not impaired and does not contribute an upstream load. No percentage reduction was required in Lower Blacks Fork or Muddy Creek because the data show that they are not in violation of the *E. coli* standard. The percentage reductions in Table 5.8 were applied to current loads using the equation below to generate TMDLs (Table 5.9) that were ultimately used to determine load allocations (LAs) and to build the implementation plan.

$$\text{TMDL} \quad = \quad \text{current load} \times (1 - \text{percentage reduction})$$

Table 5.7. Percentage Reduction Required in each Hydrologic Regime

Hydrologic Regime		Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
Climate	Season	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	Spring	0%	0%	0%	0%	0%	71%	0%	0%	14%	0%	0%
	Summer	0%	0%	65%	38%	0%	29%	86%	0%	64%	0%	0%
	Fall	0%	0%	62%	0%	0%	49%	78%	0%	39%	0%	0%
Dry	Spring	0%	0%	0%	5%	0%	63%	44%	0%	13%	0%	0%
	Summer	0%	17%	34%	0%	0%	69%	71%	0%	62%	0%	0%
	Fall	0%	0%	33%	0%	0%	67%	63%	0%	70%	0%	0%
Wet	Spring	0%	0%	0%	0%	0%	27%	24%	0%	0%	0%	0%
	Summer	0%	0%	55%	46%	0%	73%	20%	0%	65%	0%	0%
	Fall	0%	0%	41%	40%	0%	49%	82%	0%	71%	0%	0%

Table Key: Highest occurring percentage reduction in each of the four impaired reaches. Reach 2 has a 0% reduction in all hydrologic regimes and is therefore not highlighted.

Table 5.8. Percentage Reduction Required in each Impaired Reach

Reach	Location	Percentage Reduction
1	Blacks Fork from Smiths Fork upstream to Millburne	65%
2	Blacks Fork from Hams Fork upstream to Smiths Fork	0%
3	Smiths Fork from Blacks Fork upstream to Cottonwood Creek	71%
4	Smiths Fork from Cottonwood Creek upstream to the East Fork and West Fork of Smiths Fork	86%

Table 5.9. Total Maximum Daily Loads (G-cfu) Calculated for each Impaired Reach for each Season under the Nine Hydrologic Regimes

Hydrologic Regime		Impaired Reach 1	Impaired Reach 4	Impaired Reach 3	Impaired Reach 2
Climate	**Season**				
Normal	Spring	11,346	10,691	12,269	2,371
	Summer	7,792	14,340	12,688	436
	Fall	1,814	2,420	1,926	96
	Total allowable load (normal)	*20,952*	*27,451*	*26,882*	*2,903*
Dry	Spring	2,901	3,185	3,899	15,732
	Summer	1,945	4,070	6,297	240
	Fall	514	904	2,085	78
	Total allowable load (dry)	*5,360*	*8,159*	*12,282*	*16,050*
Wet	Spring	16,598	13,274	22,077	13,178
	Summer	24,485	12,531	31,654	3,714
	Fall	4,267	5,027	8,840	693
	Total allowable load (wet)	*45,351*	*30,832*	*62,571*	*17,585*

5.2.1.2. LOAD REDUCTION ESTIMATES

The TMDL identifies the need to reduce pathogens from sources by 65% in Reach 1, 71% in Reach 3, and 86% in Reach 4 during the normal climate impairment season (May–September). For Reach 1, a 65% reduction translates to a reduction of the *E. coli* load of 38,912 G-cfu/season. For Reach 3, a 71% reduction translates to 65,815 G-cfu/season and for Reach 4, an 86% reduction equates to 168,627 G-cfu/season. Tributaries contributing loads to impaired reaches will also require a reduction. For Blacks Fork Headwaters and Blacks Fork subwatersheds, a 65% reduction is required, translating to a reduction load of 6,077 and 18,128 G-cfu/season, respectively. For Cottonwood Creek, a 71% reduction is required, resulting in a 71 G-cfu/season load reduction.

5.2.1.3. DAILY TOTAL MAXIMUM DAILY LOADS

To ensure that TMDLs were protective of the single sample maximum concentration standard (235 cfu/100 mL), daily loads were calculated based on the seasonal TMDLs (see Table 5.9). The TMDLs from Table 5.10 were divided by the number of days that occur during the impairment season (152) and then compared to daily loads calculated using modeled flows and the single sample maximum concentrations (Table 5.11). Results show that TMDLs are protective of the single sample standard (Figure 5.3).

Table 5.10. Daily Total Maximum Daily Loads (G-cfu/day) Calculated for each Subwatershed for the Three Climatic Conditions

Climate	Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	22	64	74	113	17	76	133	0	177	1	19
Dry	16	60	14	29	11	19	47	0	81	0	106
Wet	37	251	164	245	43	141	141	1	412	3	116

Table 5.11. Daily Standard Water Quality Loads (G-cfu/day) Calculated for each Subwatershed for the Three Climatic Conditions Using the Single Sample Maximum Concentration

Climate	Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	1,929	943	400	535	599	343	578	108	686	226	2,254
Dry	1,288	548	83	170	318	89	247	23	271	23	507
Wet	2,794	2,779	1,080	1,236	1,212	902	1,212	280	1,527	526	5,639

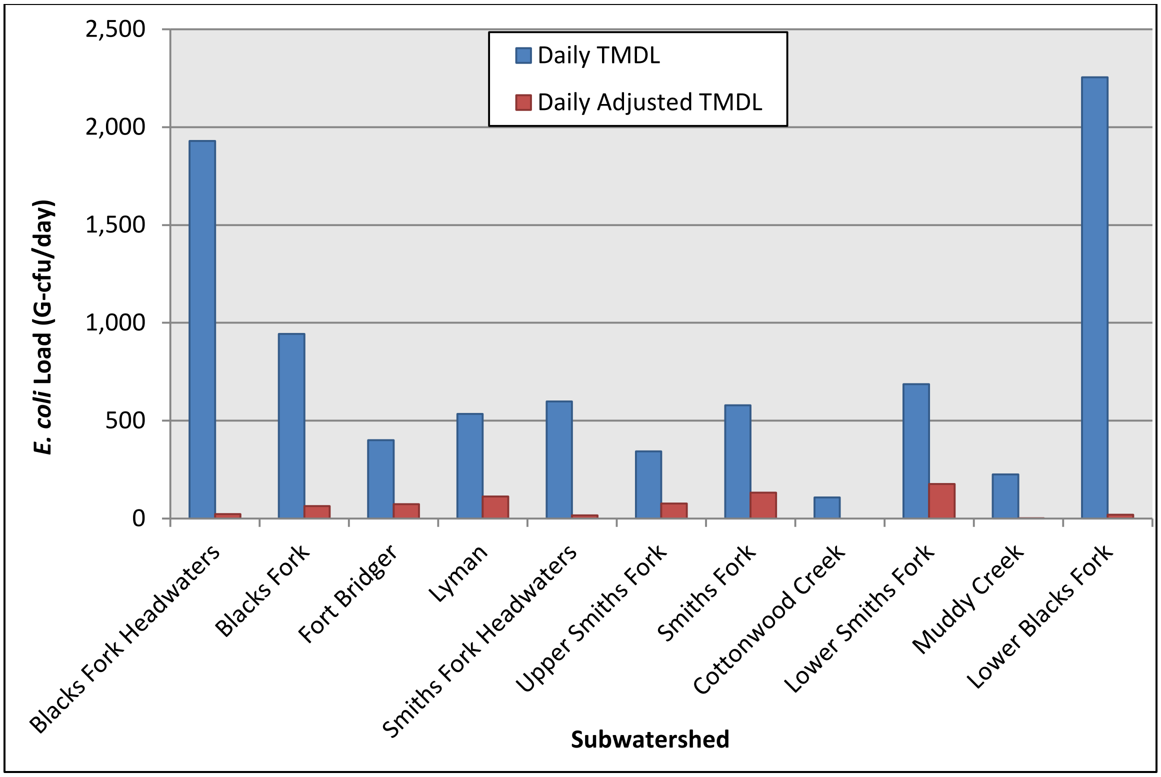

Figure 5.3. Daily standard water quality load for single sample maximum concentration versus the daily total maximum daily load during a normal climate condition.

5.2.2. Current Load Summary for the Winter Season (October–April)

A winter TMDL was also calculated to ensure that the winter season contact standard was not being violated. Based on all available geomean data from October to April and modeled flows from the Blacks Fork basin hydrologic model, current loads and TMDLs (Tables 5.12 and 5.13) were generated. Findings reveal that no winter violations occur.

Table 5.12. Current Loads (G-cfu) Calculated for each Subwatershed for the Winter Season under Three Climatic Conditions

Climate	Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
	Blacks Fork Headwaters	**Blacks Fork**	**Fort Bridger**	**Lyman**	**Smiths Fork Headwaters**	**Upper Smiths Fork**	**Smiths Fork**	**Cottonwood Creek**	**Lower Smiths Fork**	**Muddy Creek**	**Lower Blacks Fork**
Normal	315	1,023	845	2,358	223	37,743	5,471	68	1,482	225	6,681
Dry	186	589	447	1,255	139	22,598	3,218	32	837	81	3,631
Wet	381	768	1,184	3,327	301	51,833	6,682	94	2,086	536	10,642

Note: Total winter load represents the load from October to April.

Table 5.13. Total Maximum Daily Loads (G-cfu) Calculated for each Subwatershed for the Winter Season under Three Climatic Conditions

Climate	Impaired Reach 1				Impaired Reach 4			Impaired Reach 3		Impaired Reach 2	
	Blacks Fork Headwaters	Blacks Fork	Fort Bridger	Lyman	Smiths Fork Headwaters	Upper Smiths Fork	Smiths Fork	Cottonwood Creek	Lower Smiths Fork	Muddy Creek	Lower Blacks Fork
Normal	157,628	156,539	118,680	137,562	111,557	106,010	123,224	29,759	152,983	99,143	601,330
Dry	92,915	90,139	62,801	73,205	69,723	63,472	72,475	13,886	86,363	35,593	326,788
Wet	190,481	117,435	166,155	194,034	150,492	145,586	150,488	41,528	215,326	236,020	957,793

Note: TMDL winter load represents the load from October to April.

5.2.3. Margin of Safety

The CWA requires that the total load capacity "budget" calculated in TMDLs must also include a margin of safety (MOS). The MOS accounts for uncertainty in the loading calculation. The MOS can differ for each waterbody due to variation in the availability and strength of data used in the calculations. The MOS can be incorporated into TMDLs by the use of conservative assumptions in the load calculation, or it can be specified explicitly as a proportion of the total load. The Blacks Fork TMDL relies on conservative assumptions in the TMDL calculations to meet the MOS requirement primarily through applying the most protective percentage reduction to all subwatersheds contributing to the impairment across all seasons. This methodology ensures that load reductions are more than sufficient for each subwatershed during different seasons and climate conditions.

5.3. Load Allocation and Rationale

The EPA provides guidance in allocating loads to point and nonpoint sources in TMDLs. The *Protocol for Developing Pathogen TMDLs* states that dividing the assimilative capacity of a given waterbody among sources should consider the following issues: economics, political considerations, feasibility, equitability, types of sources and management options, public involvement, implementation, limits of technology, and variability in loads and effectiveness of BMPs (EPA 2001). All of these have been considered in determining LAs for the Blacks Fork TMDLs. The following allocation and implementation processes are based on loads during a normal climate condition across the entire impairment season (May–September). The normal climate condition was chosen because it was found to be protective of the wet and dry climate conditions and is the most likely condition to occur at 55% versus 24% and 21% of the dry and wet conditions, respectively.

5.3.1. Wasteload Allocations

WLAs were determined using the design flow of each WWTP facility and the *E. coli* concentration for which each plant is permitted (Table 5.14). Loads were calculated by month and then summed by the appropriate season. Effluent limits for *E. coli* for all four facilities mirror the instream *E. coli* standard (126 cfu/100 mL). Given that all treatment plants in the Blacks Fork Watershed are currently operating below load allocations, no reduction is required.

Table 5.14. Wasteload Allocations (G-cfu) Calculated for each Point Source for each Season

Season	Fort Bridger Sewer District	Lyman Wastewater Lagoon	Mountain View Wastewater Lagoon	Travel Centers of America
Spring	102	168	116	4
Summer	104	171	118	4
Fall	51	84	58	2
Total	**257**	**326**	**292**	**10**

5.3.2. Nonpoint Source Load Allocation

LAs were identified for each impaired water and contributing tributary in the Blacks Fork Watershed. Impaired reaches consisting of more than one subwatershed (Reach 1 and 4) were given compliance points, identified as the most downstream point of each subwatershed in the impaired reach. Although the Lower Blacks Fork subwatershed (Reach 2) is listed as impaired, the data indicate that there is no impairment, therefore Lower Blacks Fork and Muddy Creek subwatersheds were not included in the LA process or implementation plan. Additionally, because there is no upstream *E. coli* load from Smiths Fork Headwaters, it was also not included in the LA process.

Nonpoint source LAs represent the remaining load capacity after WLAs and future LAs have been accounted for. The nonpoint source LA was used to calculate a percentage reduction for each subwatershed that was then applied to all nonpoint sources to generate individual LAs per source (Table 5.15). During the normal climate impairment season, upstream LAs are greatest for Reach 3, whereas livestock LAs are greatest for Reach 1 and Reach 4 (Figure 5.4).

Table 5.15. Load Allocations (G-cfu) Calculated for each Compliance Point for the Normal Climate Condition During the Impairment Season (May–September)

Impaired Reach	Compliance Point*	Upstream LA	Diverted LA	Septic LA	Pet Waste LA	Wildlife LA	Livestock LA	Total LA
1	Lyman, Fort Bridger	534	1,819	723	270	1,460	15,239	20,046
3	Lower Smiths Fork	22,215	–	0	1	851	3,815	26,882
4	Upper Smiths Fork, Smiths Fork	0	2,621	556	113	1,410	22,053	26,753
Contributing Tributaries	Blacks Fork Headwaters	0	–	22	5	1,932	1,307	3,266
	Blacks Fork	1,329	–	56	8	291	8,061	9,746
	Cottonwood Creek	0	–	0	0	8	21	29

* Compliance points are identified as the most downstream point of each subwatershed in the impaired reach.

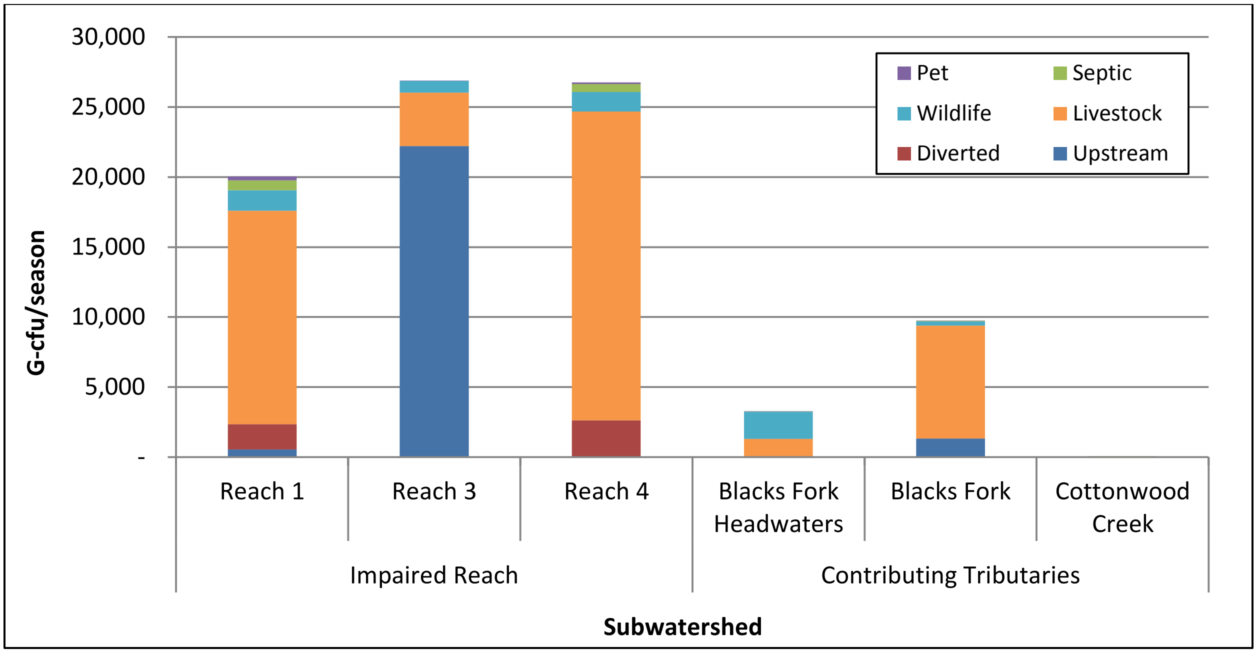

Figure 5.4. Load allocations for nonpoint sources in the impaired reaches and contributing tributaries during a normal climate condition impairment season.

5.4. Future Growth

The Blacks Fork Watershed is 1,343,732 acres, 67% of which is in Uinta County, Wyoming. Understanding future population growth at the watershed scale requires an examination of both countywide projected population estimates and historical population growth for the towns of Lyman, Mountain View, and Fort Bridger. Future population growth for these three towns was estimated using census data from 2000 and 2010 (U.S. Census Bureau 2010). Lyman and Mountain View were found to increase by approximately 7% and 9%, respectively. An increase of a similar magnitude was assumed for Fort Bridger (8%) because no historical or future population data exist. Future populations for each town are shown in Table 5.16. Currently, all three WWTPs in the Blacks Fork watershed are operating well below design flows. Average seasonal flows recorded during a normal climate condition are 0.19, 0.28, and 0.28 MGD for Fort Bridger, Lyman, and Mountain View, respectively. Given the relatively small increase in population, all treatment plants will continue to be within their capacity to process the increase in flows from a growing population. Therefore, no future WLAs were assigned to any treatment plant.

Table 5.16. Projected Population Growth for Towns in the Blacks Fork Watershed

Town	2010	2020	2030
Lyman	2,115	2,263	2,421
Mountain View	1,286	1,402	1,528
Fort Bridger	345	373	402

Note: Based on a 7%, 8%, and 9% increase in population for Lyman, Fort Bridger, and Mountain View.

It was also important to consider the Blacks Fork Watershed population outside of the three existing towns. No population data exist at this watershed scale, therefore population projection estimates for Uinta County, Wyoming, were used as a proxy for growth in the more rural outlying areas. Uinta County, Wyoming, is estimated to increase in population by approximately 10% by 2030 (State of Wyoming 2010). If a similar growth rate is assumed for the Blacks Fork Watershed, then a 10% increase in the load contribution from septic systems could be expected. During a normal climate condition, a 10% increase would result in future LAs in the amount of 237 G-cfu/season for Reach 1 and 407 G-cfu/season for Reach 4.

5.5. Seasonality

The most important seasonal aspect to consider for the Blacks Fork TMDL is the distribution of *E. coli* loads across the entire impairment season. The primary contact standard for *E. coli* is a geomean of ≤ 126 cfu/100 mL between May 1 and September 30. Based on local knowledge of irrigation practices in the region, this impairment season was separated into three irrigation seasons. According to the UCCD, irrigation occurs early in the spring from May through June. Little to no irrigation occurs when hay is being cut, generally July through August. A second irrigation may occur in September and October if water is available.[3] As such, May and June are considered the spring loading season, whereas July and August are considered the summer loading season because this timeframe reflects summer thunderstorms and low flow with little influence from irrigation. The fall loading season (September) accounts for loading generated from storm events and any additional irrigation late in the growing season. Categorizing loading in this manner becomes important for recognizing when the greatest impairment is occurring and identifying appropriate implementation measures.

For a normal climate condition, the highest absolute loads are typically delivered during the spring and summer seasons. High loads in the spring are a result of greater flows, whereas high loads in the summer are a result of higher concentrations. This pattern changes when comparing current loads to TMDLs because the highest percentage reductions needed often occur exclusively during the summer season, with the exception of the Upper Smiths Fork subwatershed.

5.6. Total Maximum Daily Loads Summary

A TMDL summary for each impaired reach is presented in Table 5.17. The summary includes current loads and TMDLs for both the entire impairment season as well as the 60-day critical season. Loads are also presented as daily values for both the impairement season and critical 60-day season.

[3] Personal communication, Technical Advisory Committee conference call between Erica Gaddis, SWCA, and Kerri Sabey, UCCD, regarding irrigation practices, August 29, 2013.

Table 5.17. Summary of Seasonal and Daily *E. coli* loads for Attainment of Water Quality Standards in the Blacks Fork and Smiths Fork Rivers.

	Seasonal Loads		Daily Loads	
	Seasonal Load (May–September) (G-cfu/season)	**Seasonal Load (60-day) (G-cfu/season)**	**Daily Load (May–September) (G-cfu/day)**	**Daily Load (60-day) (G-cfu/day)**
Reach 1				
Current load	59,863	22,264	393.8	371.1
TMDL	20,952	7,792	137.8	129.9
WLA for point sources	691	279	4.5	4.7
Nonpoint source LA	20,046	7,420	131.9	123.7
MOS	0	06.32	0	0
Future growth LA	215	93	1	1.6
Reach 2				
Current load	2,903	436	19.1	7.3
TMDL	2,903	436	19.1	7.3
WLA for point sources	0	0	0	0
Nonpoint source LA	0	0	0	0
MOS	0	0	0	0
Future growth LA	0	0	0	0
Reach 3				
Current load	92,697	43,750	611.6	729.2
TMDL	26,882	12,688	176.9	211.5
WLA for point sources	0	0	0	0
Nonpoint source LA	26,882	12,688	176.9	211.5
MOS	0	0	0	0
Future growth LA	0	0	0	0
Reach 4				
Current load	196,078	102,432	1,290.0	1,707.2
TMDL	27,451	14,340	180.6	240.5
WLA for point sources	292	118	1.9	2.0
Nonpoint source LA	26,753	14,012	176.0	233.5
MOS	0	0	0	0
Future growth LA	407	211	2.7	3.5

6. UNCERTAINTY AND VARIABILITY

Sources of uncertainty and variability associated with the analysis relate to data representativeness or the uncertainty and variability for data used for calibration; uncertainty and variability in the values used to characterize processes and sources; and uncertainty in the understanding of the processes occurring in the watershed and how these processes are represented by the analysis. These issues are discussed with respect to the analysis presented in this TMDL for both the load analysis and source identification.

6.1. Load Analysis

Uncertainty and variability associated with the load analysis are primarily due to the representativeness of *E. coli* concentration data that were used to generate geomeans. Each of the 11 subwatersheds required geomeans for 9 hydrologic regimes, and although most of those values are robust (e.g., at least five discrete samples used to build the geomeans), in some cases, extrapolation was required to fill data gaps. For the Cottonwood Creek subwatershed, only five samples were available, all of which were taken in April 2002. The geomean generated by those five samples (1.43) was used to represent all hydrologic regimes. This geomean was also applied to Muddy Creek subwatershed because there were no available concentration data and because the two sites share similar land use and topographical characteristics. There were also no available concentration data to represent the Smiths Fork headwaters subwatershed; in this case, the geomean for Blacks Fork headwaters was applied because those two sites also share similar land use and topographical characteristics. Lower Blacks Fork subwatershed also had limited data availability, and gaps were filled by calculating a geomean using only six samples. The winter-wet regime was lacking values in all subwatersheds; in these cases, the values for winter-normal and winter-dry were combined to generate a geomean. Lastly, no data were available for the winter-dry value in Lyman, therefore the geomean from May and June (132) of that same climate condition was applied.

6.2. Source Identification

Partitioning current *E. coli* loads into the four loading categories (wastewater, diverted, upstream, and watershed) required the use of assumptions and extrapolation in cases where data were not available. For wastewater loads, where monthly *E. coli* averages were not available (Town of Lyman and Fort Bridger Sewer District), the monthly reported geomean from the discharge monitoring report was used. In cases where the monthly geomean was not available, seasonal averages from the other two climate conditions were used (Fort Bridger Sewer District).

Calculating diverted loads required the use of geomeans from water quality sites that did not necessarily occur at the point of diversion or return. In some cases, nodes that represented irrigation flows were positioned between two water quality stations (see Table 4.3); therefore, a geomean calculated from concentration data at both sites was used.

Calculation of upstream loads required estimation of *E. coli* die-off in the stream, after accounting for loads delivered to or diverted from the subwatershed by irrigation canals. Die-off coefficients were generally calculated using measured velocity and temperature data where possible, although velocity was estimated in some seasons based on flow. In some cases, die-off coefficients were calibrated to match known load transfers. For example, upstream loads were initially predicted to be higher than the total load in the Lower Smiths Fork subwatershed and Lower Blacks Fork subwatershed. In these cases, die-off coefficients were modified to represent the change in slope and potential sedimentation of *E. coli* in the reach.

6.2.1. Watershed Loads

6.2.1.1. WILDLIFE

There is a great deal of variability associated with seasonal population estimates for wildlife species because seasonal migration patterns can be very fluid. Local weather patterns, forage availability, hunting pressure, predators, foraging competition, and human disturbance can all affect wildlife population movements on a monthly basis.[4] Furthermore, this matrix of factors affects each species differently, making precise identification of location during any point of the year a difficult exercise. The seasonal range maps employed in this study for generating monthly estimates are typically used on a much larger spatial scale. Although estimates reported in this document are reasonable and appropriate for incorporation into the BSLC, numbers should be considered with caution.

6.2.1.2. LIVESTOCK

The degree of variability associated with total livestock estimates is evident in that reported numbers from the USDA census of agriculture represent spatial scales that are very different than subwatersheds. The census of agriculture reported county-wide numbers that then had to be scaled to the subwatershed using total acreage. Total acreage as a proxy for livestock estimates could lead to over- or under-estimates because livestock are not necessarily evenly distributed across the subwatershed landscape.

Estimating livestock populations on private land was also subject to variability for both the summer and winter counts. Misidentification of a species was a possibility due to the presence of buffalo and horses in the landscape that could have been mistaken for cattle. For the winter count, imagery was not available for 41% of the private land, therefore population estimates had to be extrapolated using data collected from the private land that was surveyed. This method assumed a similar distribution of cattle across areas of private land that were not surveyed.

6.2.1.3. SEPTICS

It is possible that generating septic system counts using aerial imagery could have led to underestimation if houses were not visible on the imagery or were simply missed during the survey. On the other hand, overestimation was possible if structures were included that were abandoned or vacant. Final counts were verified against U.S. Census Bureau data and sewered estimates so that there is a considerable amount of confidence in the final numbers.

7. PUBLIC PARTICIPATION

7.1. Technical Advisory Committee

The experience, knowledge, and data held by various agencies and stakeholders have been invaluable to the development of the TMDL and implementation plan for the Blacks Fork Watershed. Throughout the project, communication and coordination have occurred primarily through monthly conference calls with the technical advisory committee (TAC) (Table 5.18).

[4] Personal communication by email between Lucy Parham (SWCA) and Jeff Short [WGFD] regarding wildlife migration, November 5, 2013.

Table 5.18. Blacks Fork Watershed Technical Advisory Committee

First Name	Last Name	Affiliation
Chris	Aimone	Uinta County Weed & Pest District
Barney	Brisko	Uinta County
Jeremy	Caldwell	BLM, Kemmerer Field Office
Leah	Coleman	WDEQ, WYPDES Program
Dennis	Doncaster	BLM, Rock Springs Office
Tavis	Eddy	WDEQ, Watershed Monitoring
Spencer	Eyre	UCCD
Ken	Fackrell	Bridger Valley Conservancy District
Brianna	Forrest	WDEQ, TMDL Program
Rick	Guild	Public Works for Town of Mountain View
Carol	Hamilton	UCCD, Watershed Resident
Andy	Hewitt	Town of Lyman, Mayor
Kevin	Hyatt	WDEQ, TMDL Program
Robert	Keith	WGFD
Dave	Kimble	U.S. Fish and Wildlife Service
Jennifer	Lamb	The Nature Conservancy
Jeff	Lewis	Natural Resources Conservation Service
Sue	Lowry	SEO
Kirk	Miller	USGS
Roland	Petersen	WDEQ
Kerri	Sabey	UCCD
Rick	Schuler	USFS, Uinta-Wasatch-Cache
Shaun	Sims	UCCD
Jean	Stramel	Natural Resources Conservation Service
Basia	Trout	BLM, Kemmerer Field Office
Ron	Vore	Water Development Commission
Marty	Watkins	Chairman of Steering Committee
Steve	Wolff	SEO
John	Yarbrough	SEO

Minutes from these calls are available upon request to the WDEQ. Calls have occurred on the following dates:

- June 27, 2013
- July 25, 2013
- August 29, 2013
- September 26, 2013
- November 14, 2013
- December 16, 2013
- January 30, 2014
- February 27, 2014
- March 27, 2014
- April 24, 2014

7.2. Public Meetings

Two public meetings have been held in Lyman, Wyoming, at the UCCD conference room and a third is scheduled during the public comment period (June 9, 2014–July 9, 2014) for the public draft TMDL. The purpose and goals of these public meetings are summarized in Table 5.19. Each past meeting began with a presentation from the contractor followed by an open discussion.

Table 5.19. Public Meeting Agendas for the Project

Public Meeting	Date	Presentation of Completed Work	Discussion of Proposed Methods for Next Phase	Key Information Gathered and/or Goal of Meeting
First public meeting (kickoff meeting)	April 24, 2013	Draft public involvement plan Website Comment cards	Data acquisition and watershed characterization Water quality standards and targets Pollution source identification methods	• Introductions (WDEQ and SWCA) • Introduction of TAC members that will participate in monthly calls • Explanation of how to get involved in the project • Confirmation that all available data sources relevant to the project have been identified
Second public meeting	October 30, 2014	Data summary and watershed characterization Water quality targets and linkage to impairments	Proposed TMDL methodologies Implementation planning Effectiveness monitoring planning Pollution source identification	• Potential point and nonpoint sources of pathogen and sediment in the watershed • Data related to sources (e.g., grazing management, septic tanks, wildlife, channel instability, sensitive soils, riparian loss, point sources, spatial data) • Data related to hydrology and critical flows • History of implementation in the watershed and lessons learned
Third public meeting	Scheduled for June 25, 2014	TMDL results Pollution source identification results Draft implementation plan Draft monitoring plan	Schedule for draft TMDL release and incorporation of public comments	• Comments on TMDL results • Comments on draft implementation plan • Comments on draft monitoring plan

7.3. Public Comments

The Blacks Fork TMDL public draft will be completed on June 9, 2014, and made available for public review shortly thereafter. A 30-day public comment period from June 9, 2014 to July 9, 2014, was advertised in local newspapers and posted on the WDEQ and UCCD websites. The public draft TMDL was available in hard copy at the UCCD office and also available for electronic download from SWCA's client space and the WDEQ website. All comments received during the 30-day comment period will be addressed in the final document. Documentation of all comments and responses will be provided in Appendix B.

8. LITERATURE CITED

AECOM. 2008. *Technical Memorandum: Green River Basin Plan II: Task 3A-Surface Water Data Collection and Study Period Selection*. Available at: http://waterplan.state.wy.us/plan/green/2010/techmemos/GRB_Surface-Water.html. Accessed on August 30, 2012.

BLM. 2011. Rangeland Program Glossary. Available at http://www.blm.gov/ut/st/en/prog/grazing/range_program_glossary.html. Accessed on November 14, 2013.

BOR. 2009. Stateline Dam background information online. Available at: https://www.usbr.gov/projects/Facility.jsp?fac_Name=Stateline+Dam&groupName=General. Accessed on April 3, 2014.

Clark, M.L., and M.E. Gamper. 2000. *A Synoptic Study of Fecal-indicator Bacteria in the Wind River, Bighorn River, and Goose Creek Basins, Wyoming, June-July 2000*. Water-Resources Investigations Report 03-4055. Cheyenne, Wyoming: USGS National Water-Quality Assessment Program.

CLR Search. 2012. Lyman Weather, Forecast, Temperature and Precipitation. Available at: http://www.clrsearch.com/Lyman_Demographics/WY/Weather-Forecast-Temperature-Precipitation. Accessed on October 3, 2012.

Crane, S.R., and J.A. Moore. 1986. Modeling enteric bacterial die-off: A review. *Water, Air and Soil Pollution* 27(3–4):411–439.

EPA. 1985. Chapter 8: Coliform Bacteria. In *Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition)*. Athens, Georgia: Environmental Research Laboratory.

———. 1986. *Ambient Water Quality Criteria for Bacteria - 1986.* EPA 440/5-84-002. Washington, D.C.: Office of Water (4503F), EPA.

———. 2001. *Protocol for Developing Pathogen TMDLs.* EPA 841-R-00-002. Washington, D.C.: Office of Water (4503F), EPA.

———. 2012. Fecal Bacteria. Available at http://water.epa.gov/type/rsl/monitoring/vms511.cfm. Accessed on April 1, 2014.

Flint, K.P. 1987. The long term survival of Escherichia coli in river water. *Journal of Applied Bacteriology* 63:261–270.

Fry, J., G. Xian, S. Jin, J. Dewitz, C. Homer, L. Yang, C. Barnes, N. Herold, and J. Wickham. 2006. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS* 77(9):858-864. Available at http://www.mrlc.gov/downloadfile2.php?file=September2011PERS.pdf. Accessed July 29, 2013.

Love, J.D., and A.C. Christiansen (compilers). 1985. Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.

Mancini, J.L. 1978. Numerical estimates of coliform mortality rates under various conditions. *Water Pollution Control Federation* 50(11):2477–2484.

Mitchell, R., and C. Chamberlin. 1978. Survival of indicator organisms in *Indicators of viruses in water and food*, edited by G. Berg. Ann Arbor, Michigan: Ann Arbor Science Publishers.

Pratt, M., and G.A. Rasmussen. 2001. Determining your stocking rate. Utah State University Cooperative Extension. Available at: http://extension.usu.edu/files/publications/publication/nr_rm_04.pdf. Accessed on November 14, 2013.

SEO. 2011. *Green River Basin Water Plan: 2011 Final Report*. Available at: http://waterplan.state.wy.us/plan/bear/2011/finalrept/finalrept.html. Accessed on August 30, 2013.

———. 2013. Web Data Portal Real Time Data. Available at http://seoflow.wyo.gov/WDPortal/. Accessed June 26, 2013.

State of Wyoming. 2010. Wyoming Economic Analysis Division. Available at http://eadiv.state.wy.us/. Accessed on February 13, 2014.

SWCA. 2010. *Final Goose Creek Watershed TMDL*. Prepared for the WDEQ. Salt Lake City, Utah.

Town of Mountain View. 2013. Welcome to Mountain View. Available at: http://www.mountainviewwyoming.net/. Accessed on April 21, 2014.

UCCD. 2005. *Blacks For & Smiths Fork Rivers Watershed Management Plan.* Blacks Fork/Smiths Fork Water Quality Steering Committee–UCCD. Assisted by Wyoming Association of Conservation Districts, NRCS, and Wyoming Department of Agriculture.

U.S. Census Bureau. 2010. 2010 Census. Available at: http://quickfacts.census.gov/. Accessed on February 10, 2014.

USDA. 2009. 2007 Census of Agriculture county profiles for Uinta, Summit, and Lincoln Counties. National Agricultural Statistics Service. Available at: http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/County_Profiles/Wyoming/. Accessed on April 24, 2014.

Utah State University Climate Center. 2013. Information for Church Buttes Gas Platform and the Mountain View weather stations. Available at http://climate.usu.edu/mapGUI/mapGUI.php. Accessed April 29, 2013.

WDEQ. 1998. *Wyoming Ground Water Vulnerability Assessment Handbook*. Cheyenne: Wyoming Water Resources Center, University of Wyoming and the Wyoming State Geological Survey.

———. 2001b. *Wyoming Surface Water Classification List (Table A). June 21, 2001 update.* Cheyenne, Wyoming: WQD.

———. 2007. *Water Quality Rules and Regulations, Chapter 1, Wyoming Surface Water Quality Standards.* Cheyenne: WDEQ, WQD.

———. 2011. Coliform Bacteria Sampling Procedure. Available at: http://deq.state.wy.us/wqd/watershed/Downloads/QA/12-0698-JAC-SOP_July2012.pdf. Accessed November 15, 2013.

———. 2012. *Wyoming Water Quality Assessment and Impaired Waters List (2012 Integrated 305(b) and 303(d) Report).* Cheyenne, Wyoming: WDEQ, WQD, Watershed Section. Available at: http://deq.state.wy.us/wqd/watershed/Downloads/305b/2012/WY2012IR.pdf. Accessed November 15, 2013.

———. 2013a. *Wyoming Water Quality Rules and Regulations*. Chapter 1, Wyoming Surface Water Quality Standards. Available at: http://deq.state.wy.us/wqd/WQDrules/Chapter_01.pdf.

———. 2013b. Wyoming Surface Water Classification List. Water Quality Division Surface Water Standards, June 21, 2001. Updated July 26, 2013. http://deq.state.wy.us/wqd/watershed/surfacestandards/Downloads/Standards/Wyoming_Surface_Water_Classification_List_07262013.pdf.

———. 2013c. *Wyoming's Method for Determining Water Quality Condition of Surface Waters and TMDL Prioritization Criteria for 303(d) Listed Waters*. Available at: http://deq.state.wy.us/wqd/watershed/surfacestandards/Downloads/Standards/WyomingMethods_13_0352.pdf. Accessed April 2, 2014.

———. 2013d. *Shoshone River Total Maximum Daily Load Project*. Available at: http://deq.state.wy.us/wqd/watershed/TMDL/Shoshone%20TMDL/ShoshoneTMDL.htm. Accessed on April 28, 2013.

———. Wyoming Pollutant Discharge Elimination System. Permits available at http://deq.state.wy.us/wqd/wypdes_permitting/WYPDES_PNs_and_appr_permits/Pages/issued_permits.asp. Accessed on January 7, 2014.

WGFD. 2011. Places to Fish in Wyoming. Available at: http://wgfd.wyo.gov/web2011/fishing-1000428.aspx. Accessed on April 2, 2014.

WWC Engineering. 2006. *Blacks Fork/Smiths Fork Watershed Report*. Prepared for UCCD. Sheridan, Wyoming. Available at: http://deq.state.wy.us/wqd/watershed/TMDL/Blacks%20Fork%20Watershed%20TMDL/BF-SF%20Watershed%20Report.pdf. Accessed August 30, 2013.

WWDC. 2009. Blacks Fork River Basin Planning Model. Developed for the WWDC in August 2000, by States West Water Resource Consulting Engineers, Boyle Engineering Corporation. Updated May 2009 by Western Water Consultants, AECOM (formerly Boyle Engineering Corporation). Available at: http://waterplan.state.wy.us/plan/green/2010/models/models.html. Accessed on October 3, 2012.

Wyoming Department of Administration and Information: Economic Analysis Division. 2011. Wyoming Economic Analysis Division. Available at http://eadiv.state.wy.us/. Accessed on February 13, 2014.

Wyoming Office of Tourism. 2014. Bridger Valley Historic Byway. Available at: http://www.wyomingtourism.org/thingstodo/detail/Bridger-Valley-Historic-Byway/31240. Accessed on April 21, 2014.

Wyoming Water Development Office. 2003. Wind/Bighorn Lands Mapping and Water Rights Data. Available at: http://waterplan.state.wy.us/plan/bighorn/techmemos/mapping.html. Accessed on February 26, 2014.

This page intentionally blank